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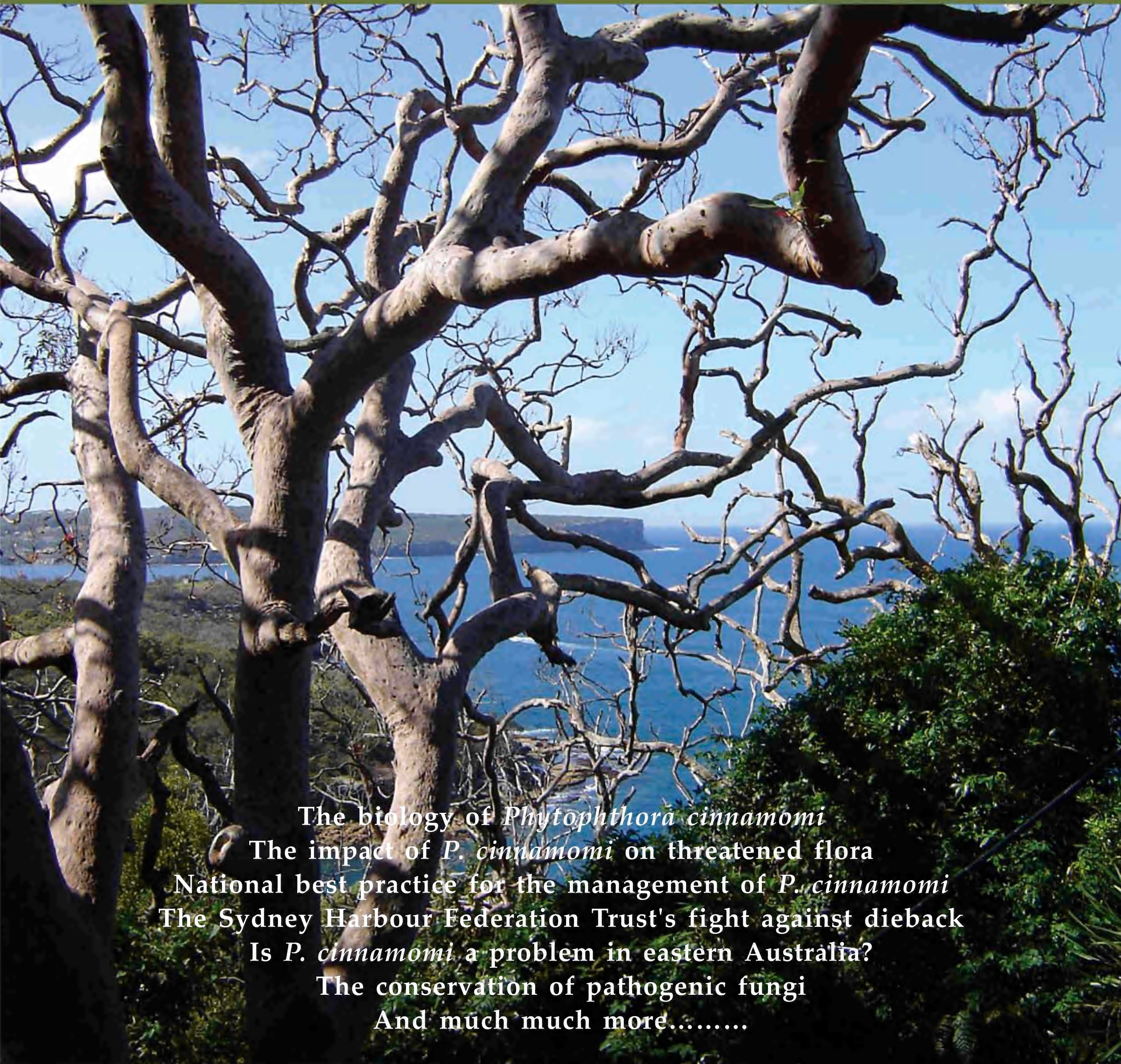

The biology of *Phytophthora cinnamomi*

The impact of *P. cinnamomi* on threatened flora

National best practice for the management of *P. cinnamomi*

The Sydney Harbour Federation Trust's fight against dieback

Is *P. cinnamomi* a problem in eastern Australia?

The conservation of pathogenic fungi

And much much more………

Special Edition: PATHOGENS AND PLANT CONSERVATION

This Issue

Regular Features

Australasian Plant Conservation Editorial Team

Fiona Hall and Tricia Hogbin. Thanks also to Kirsten Cowley and Sally Stephens.

Layout & Graphic Design

Siobhan Duffy

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ANPC Inc. Mission Statement

"To promote and develop plant conservation in Australia"

Contributing to *Australasian Plant Conservation*

Australasian Plant Conservation is a forum for information exchange for all those involved in plant conservation: please use it to share your work with others. Articles, information snippets, details of new publications or research, and diary dates are welcome. The deadline for the June-August 2005 issue is Monday 4th July 2005. The June-July issue will be a special edition on cryptogam conservation (see note on page 1). Articles not on this theme are still welcome.

Authors are encouraged to submit images with articles or information. Please submit images as clear prints, slides, drawings, or in electronic format. Electronic images need to be at least 300 dpi resolution, submitted in at least the size that they are to be published, in tif, jpg or gif format.

Please send typed or handwritten articles, no more that 2 A4 pages (or 1100 words), by fax, mail, email, or on diskette. If sending by email, please send as a MS Word (2000 compatible) or rich text format attachment to: anpc@deh.gov.au.

Front cover: View of Dieback-affected Angophoras (*Angophora costata*) at Middle Head, Sydney Harbour. Photograph: Peter Jensen. **Cover design:** Siobhan Duffy.
Printed by: Pirion, Canberra.

President's report

Judy West

Centre for Plant Biodiversity Research
CSIRO Plant Industry

Amongst the most severe current threats to global biodiversity are human-induced processes such as land use change and invasive species. Fragmentation of habitat, being one of the consequences of these processes, is often recognised as the number one threat to biodiversity and as such has attracted considerable research effort. The field of restoration ecology is rapidly developing principles and practices to address these major issues.

The strength of ANPC is in the effective transfer and exchange of skills linking the outcomes of scientific research to on-ground practitioners. This has recently been recognised by the NSW Environmental Trust through additional support to enable ANPC to run the Translocation of Threatened Plants Workshop in three regional areas of NSW this year. The first of these will be held in Queanbeyan on Wednesday 18th May followed by Newcastle in July and Coffs Harbour in August. See page 32 of this issue for additional information.

Staff of the ANPC office are also currently developing programs for another three workshops to be held in regional NSW during the remainder of 2005, largely funded by the NSW Environmental Trust. These workshops on rehabilitation of disturbed native vegetation are scheduled for Armidale, Wagga Wagga and Dubbo. An additional grass identification workshop will be offered in Dubbo. Details of these workshops can be found on the ANPC website - http://www.anbg.gov.au/anpc/course1.html

The next issue of APC will be a SPECIAL EDITION on:

CRYPTOGAM CONSERVATION

Articles and short notes about the conservation of cryptogams are invited.

Cryptogams are mosses, liverworts, hornworts, lichens, fungi and algae. They are often overlooked, but are worthy of conservation in their own right and because of their important roles in ecosystem functioning (such as in soil crusts).

The special issue will cover various approaches to the conservation of cryptogams, from a focus on individual species or communities to investigations on how habitat can best be managed for cryptogams. Articles on any groups of cryptogams are welcome. We are also interested in articles that deal with the inter-relationships between cryptogams and other plants and animals that are themselves endangered (such as the interaction between mycorrhizal fungi and orchids, or truffles as food for endangered mammals).

Please contact Tom May (tom.may@rbg.vic.gov.au, 03 9252 2319) if you wish to contribute.

See title page section on 'Contributing to *Australasian Plant Conservation*' for information on preparation and submission of articles.

Have you renewed your membership for 2005?

Please check the flysheet if you are uncertain. The year you have paid up to appears on the flysheet above your address. If you wish to renew, please complete a membership form (download from www.anbg.gov.au/anpc/membfm05.pdf) and return to the ANPC National Office. Only those who have renewed for 2005 will receive the next issue of APC.

Plans for the National Conference on **Plant Conservation: The Challenges of Change** are progressing well. This year's conference will be held in Adelaide from 26th September to 1st October, hosted jointly with the South Australian Department for Environment and Heritage and the Botanic Gardens of Adelaide. Four sub-themes have been recognised to tease out the challenges we are facing in plant conservation into the future –

1. Extreme policy changes
2. Urban ecology
3. Using revegetation to achieve ecological outcomes
4. Indigenous interests in conservation

Abstracts for papers are due June 17 – see www.plevin.com.au/ANPC2005

See the back cover of this issue for further information.

The conference will include two days of scientific program, a field day and two days of workshops, several of which arose from suggestions made in the evaluation forms submitted by participants in last year's South East Queensland workshops.

I would like to remind you that subscriptions to ANPC for 2005 are now overdue. Several members, both renewing and new, have taken up our new 3-year membership offer (for the price of 2.5 years membership). However, many members have not yet renewed for 2005. We urge you to renew your membership if you have not yet done so - members are vital to the organisation's future.

The recent announcement that the Australian Government is proposing to discontinue its support for environmental and community groups is very disappointing. The Grants to Voluntary Environment and Heritage Organisations (GVEHO) have played a significant role in supporting the infrastructure of many NGOs carrying out diverse activities and functions in the community. It has always seemed to represent an enlightened program with the government essentially funding conservation and environment groups to keep an eye on them and to lobby about conservation issues.

I hope this special edition of APC on "Pathogens and Plant Conservation" is a stimulus to many of you and results in increased recognition of the role of pathogens in the ecosystem. The ANPC greatly appreciates the Sydney Harbour Federation Trust's sponsorship towards this issue of *Australasian Plant Conservation.*

The biology of *Phytophthora cinnamomi*

Brett Summerell, Ratiya Pongpisutta and Christopher Howard

Botanic Gardens Trust, Sydney. Email: Brett.Summerell@rbgsyd.nsw.gov.au

Phytophthora root rot is a significant cause of death of trees and shrubs and as a result is a serious threat to biodiversity in many parts of Australia. The disease is common wherever there is enough water to allow the pathogen to be active, even for a small period of time, and consequently the disease is generally restricted to moister parts of the country and unlikely to occur in arid and semi-arid regions. *Phytophthora cinnamomi* is the most common and important species of *Phytophthora* causing root rot. While other species of *Phytophthora* may cause disease, it is generally less severe.

The pathogen

Traditionally the Stramenopile genus *Phytophthora* was considered a fungus, and indeed it shares many characteristics with fungi. However, it is not a true fungus and is classified in the kingdom Chromista with many organisms like the Protists and some algae. There are many species of *Phytophthora* and differentiating different species is extremely difficult but very important as they can vary significantly in their aggressiveness as pathogens. *Phytophthora cinnamomi* occurs worldwide, affecting an enormous variety of different plant species and was first described in 1922 from isolations from *Cinnamomum burmanii* trees in south-east Asia. Not long after that the pathogen was first associated with disease in horticultural crops in Australia and in 1948 the pathogen was associated with disease symptoms in native vegetation in Australia.

All of the characteristic features of *P. cinnamomi* are microscopic, so you won't be able to see it. In addition its entire life cycle takes place in the soil, making diagnosis of this organism extremely difficult. We have to recover it from roots or the soil in order to observe it. On agar media it will grow to produce a culture that you

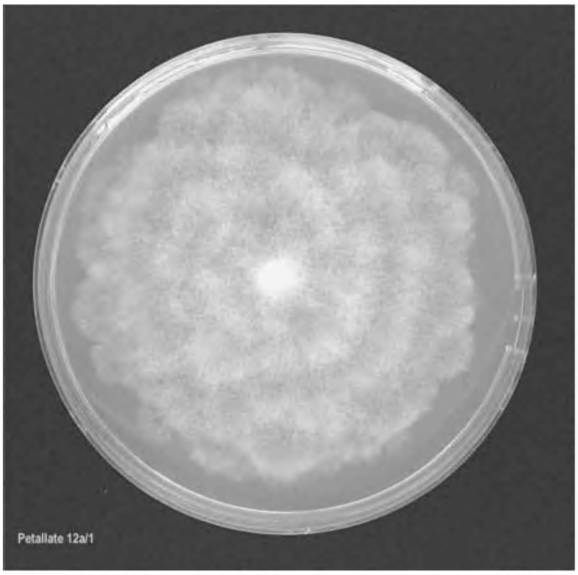

Figure 1: A culture of Phytophthora cinnamomi *growing on agar showing the typical camellioid growth pattern. Photograph: Ratiya Pongpisutta*

can observe and on rich media the culture grows in a camellioid pattern (Figure 1). Examination of this mycelium under the microscope will reveal quite distinctive hyphae with numerous spherical lumps that are diagnostic for this species (although there are some other species that can produce similar structures) (Figure 2). The critical stage of the life cycle, in so far as disease development and spread are concerned, is the sporangium (Figure 3). Within this sack-like structure are produced large numbers of asexual spores which are capable of swimming small distances and can attach to and infect roots, normally behind the root tip. *P. cinnamomi* will then grow through the root destroying the tissue so that it is unable to absorb water and nutrients. Further zoospores form in sporangia produced along the root, particularly when the soil is moist and warm, and these are released into the soil. Consequently zoospore numbers can build up quite rapidly. Zoospores move in water films in the soil and may infect neighbouring plants especially those down-slope from a site of infection. These spores are easily transported in storm water, drainage water, contaminated soil and on tools, footwear and vehicles.

A further two spore types may be produced:

- Chlamydospores (Figure 4) are survival structures produced when conditions become unfavourable such as when a food source is exhausted or in periods of low temperature or drought. These spores are capable of surviving for extended periods of time, and when conditions become favourable they germinate and renew the life cycle. This may allow *Phytophthora* to survive in dead plant tissue for a number of years.
- Oospores are the result of sexual reproduction involving exchange of genetic material between two structures known as an oogonium and an antheridium. However, these structures must be borne on the hyphae of two genetically compatible individuals of the correct mating type.

There are two mating types in *Phytophthora*, known as the A_1 and A_2 mating types, which must cross in order for an exchange of genetic material to occur (as long as environmental conditions are suitable). In most populations of *Phytophthora cinnamomi* in Australia the A_2 mating type predominates, and this has been used as a key piece of evidence, along with recent molecular data, to support the theory that *P. cinnamomi* is introduced into Australia. Interestingly recent work in our laboratory has shown that in a collection of isolates from Sydney Harbour National Park there was an equal ratio of A_1 and A_2 mating types, whilst at Werrikimbee National Park all isolates were of the A_2 mating type (Pongpisutta, unpublished data). This most probably indicates that multiple introductions of *P. cinnamomi* have occurred at Sydney Harbour NP and that there is the potential for genetic recombination to occur, whereas introductions have occurred less frequently at the more remote Werrikimbee NP.

Symptoms of the disease

Early signs of infection are often difficult to observe but include darkening of young feeder roots and occasionally the larger roots, reduction in the glossiness of leaves, leaf drop and dieback. The foliage may wilt, yellow and dry up. The base of the trunk may swell and splits may form or large cankers may develop.

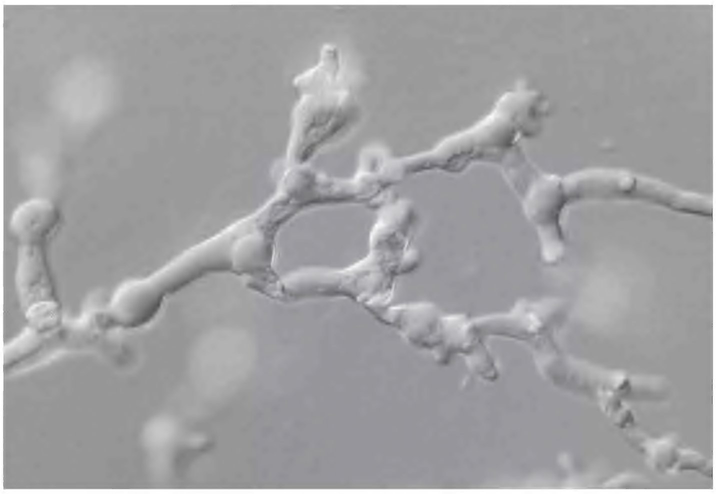

Figure 2: Mycelium of Phytophthora cinnamomi. *Photograph: Suzanne Bullock*

The infected plant may die rapidly or may hang on for some period of time. The damage caused by the disease most often occurs or is observed in summer when plants are drought stressed. The plant is unable to adequately absorb enough water from the soil because its roots are damaged and consequently often rapidly dies. The degree of symptom development is dependent on the susceptibility of the host, which can vary significantly, and on the environmental conditions. It is also worth noting that disease symptoms are also easily confused with symptoms of drought, nutrient deficiency and other pest and disease problems.

Infection and survival

Zoospores are the principal agent of infection and are attracted to the tips of fine roots. Moisture is essential for infection to occur, being needed for production of sporangia and zoospores, release of the zoospores and for the zoospore to reach the root. The zoospore will encyst on the root and penetrate the root, where the hyphae destroy the vascular tissue, thus preventing the adequate flow of water through the transpiration stream of the plant. This is why the symptoms of the disease are not unlike those of drought stress. Other propagules are also capable of initiating the disease; chlamydospores and mycelium can germinate to produce sporangia which in turn produce zoospores. Many of these propagules can survive for considerable periods of time in soil although this depends on the nature of the soil. Protracted long periods of dry soil have been associated with a decline in the survival of chlamydospores and other propagules.

Identifying the pathogen

As we have said, the symptoms of this disease are easily confused with a range of other syndromes. Consequently diagnosis of the disease frequently depends on associating disease symptoms with collecting the pathogen from root systems or the soil. Recovery of the pathogen from both roots and soil can be difficult and usually requires specialised selective media. For soil, a baiting technique that usually involves flooding the soil with water is also required. The nature of this technique is such that negative results are not definitive. This may be because the technique is not sensitive enough to detect the level of pathogen propagules present in the soil or some other factor has inhibited recovery of the pathogen. Either way, negative results need to be interpreted with some caution because of this problem.

This disease involves a complex interaction between the pathogen, host, soil and the environment. Together with the problems of accurate diagnosis, these factors make it an extremely difficult disease to limit and control.

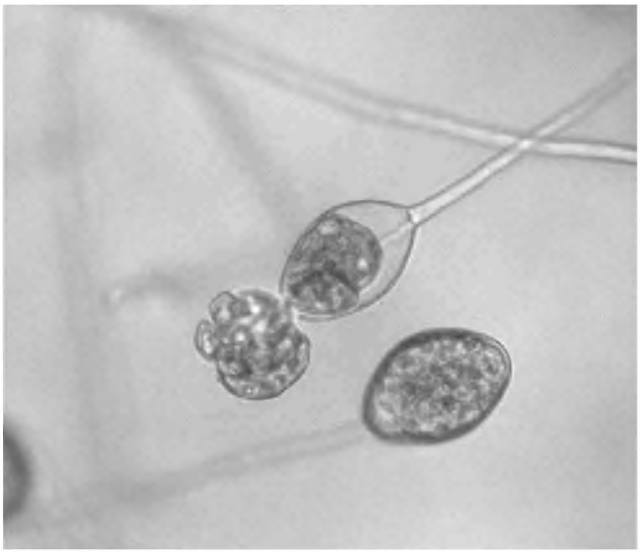

Figure 3: Sporangia of Phytophthora cinnamomi *releasing the zoospores which initiate the disease. Photograph: Ratiya Pongpisutta*

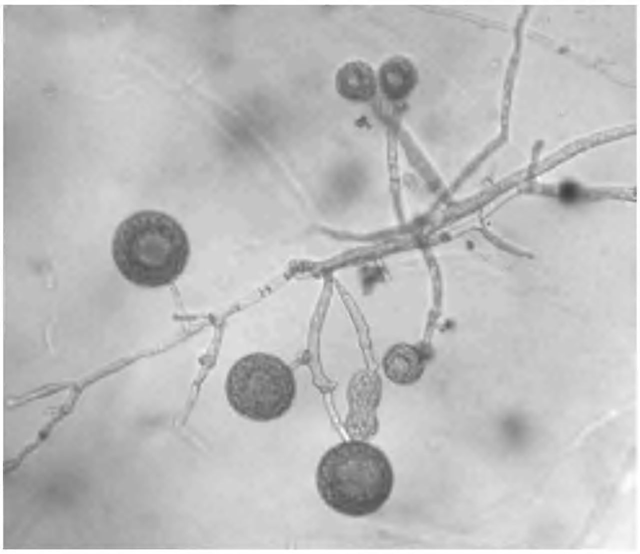

Figure 4: The survival stage, or chlamydospore, of Phytophthora cinnamomi. *Photograph: Ratiya Pongpisutta*

Our understanding of the disease in many native ecosystems is still poor and significant additional research is essential. Without this it is likely that this disease will continue to degrade native vegetation and push many species to the brink of (if not over) extinction.

The Botanic Gardens Trust offers a service for the diagnosis of *Phytophthora cinnamomi.* For details and costs please contact the Plant Disease Diagnostic Unit at (02) 9231 8186 or at pddu@rbgsyd.nsw.gov.au.

National best practice and risk assessment for the management of *Phytophthora cinnamomi* in natural ecosystems

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Disease in natural ecosystems of Australia caused by the introduced plant pathogen *Phytophthora cinnamomi* is listed as a key threatening process under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The Act requires the Commonwealth Government to prepare and implement a threat abatement plan for nationally coordinated action to mitigate the harm caused by *P. cinnamomi* to Australian species, particularly threatened flora, fauna and ecological communities. The *National Threat Abatement Plan for Dieback Caused by the Root-Rot Fungus Phytophthora cinnamomi* (Threat Abatement Plan) was released in 2001 (Environment Australia 2001). See page 29 for further details.

A national project has been funded by the Commonwealth Department of Environment and Heritage to develop:

- national ***best practice*** benchmarks for the management of sites that are, or could be, threatened by *P. cinnamomi*;
- ***risk assessment*** criteria and a system for prioritising management of sites that are, or could be, threatened by *P. cinnamomi*.

This project is considered one of the most significant actions to be implemented from the national threat abatement plan to date. The process is being undertaken by the authors and guided by an expert panel of land managers, planners and policy makers representing all states and territories except the Northern Territory, where *P. cinnamomi* is not considered to be a significant threat to biodiversity.

National benchmarks for **best practice** management of *P. cinnamomi* are being developed through a process of reviewing current management practices around Australia and identifying deficiencies in the approaches. Key stakeholders will be consulted on the benchmarks to ensure they are practical and nationally applicable.

The threat abatement plan promotes a common understanding of the national threat *P. cinnamomi* poses to biodiversity in Australia. However, current management of the threat varies greatly from state to state, and there is no state with a fully coordinated and integrated approach for management across land tenures, even though the pathogen spreads with no respect for political or economic boundaries.

The efficient and effective management of *P. cinnamomi* requires best practice to be applied at all levels of management, from legislation and policy at a strategic level, to the deployment of methods such as hygiene and quarantine at an operational level. A national best practice framework will assist in the process of developing a coordinated and consistent approach to management of the pathogen throughout Australia.

The best practice document will be relevant to government agencies, non-government agencies, industry, community conservation groups or the general public with a responsibility or interest in the management of lands that are, or could be threatened by *P. cinnamomi*. Approximately 300 stakeholders, from all states and territories, will receive the best practice document in May 2005 and be given four weeks to comment on it.

The Commonwealth Government admits in the national threat abatement plan that due to competing demands from other environmental threats, there will never be sufficient resources to protect all natural assets under threat from *P. cinnamomi*. Consequently, we are also developing a national process for **risk assessment** to identify and rank assets of high conservation value for priority management.

This risk assessment report evaluates criteria and models for assessing the risk of infestation of the pathogen *P. cinnamomi* based on a literature review of previous studies and information obtained from current studies, unpublished information and expert opinion. We are using the results of the review and evaluation to develop models suitable for assessing the risks and consequences of infestation of *P. cinnamomi* in Australia. Spatial models combine an assessment of the risks of infestation to areas with risk assessment methods for ranking species, communities, and areas. Spatial models in which risk is mapped at different scales are critically reviewed. Models have been developed that will enable flora/fauna species, communities and areas to be ranked according to the risk of *P. cinnamomi* and the ability to manage the risk, and prioritised for management. The models are designed to be practical tools to assist land managers in making decisions on the risks from *P. cinnamomi* and deciding the priorities for management and recovery actions. With input from land managers in the states

and territories, the models will be applicable nationally and at state and local levels and scales. They are due to be completed in August 2005 and will be published on the Commonwealth Department of the Environment and Heritage website (www.deh.gov.au/).

If you have any enquiries about this national project please contact Dr Emer O'Gara at Murdoch University on: Email: e.ogara@murdoch.edu.au; telephone: 08 9360 7414.

Phytophthora cinnamomi in eastern Australia

Keith L. McDougall

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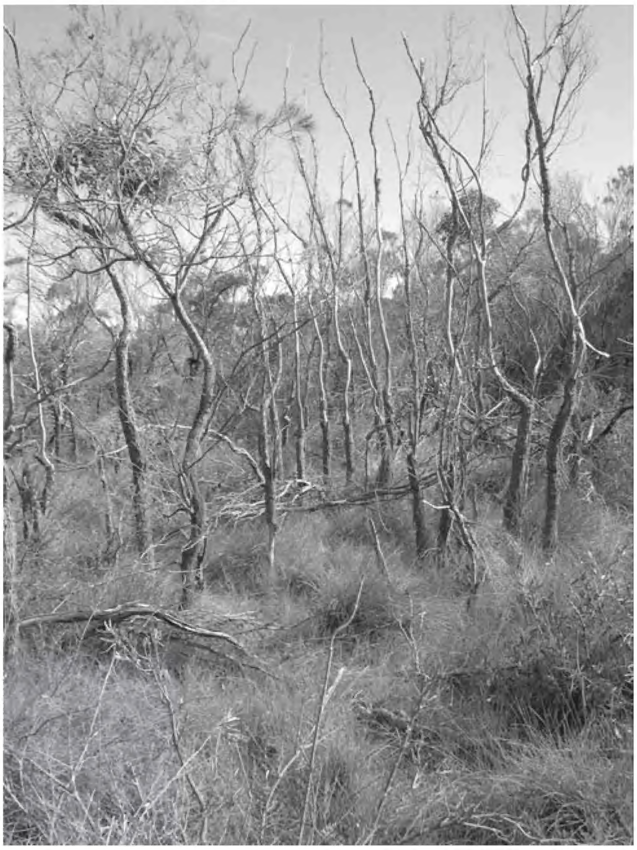
The listing of *Phytophthora cinnamomi* as a Key Threatening Process in NSW may have been a surprise to many who had come to believe that this pathogen was native, at least on the east coast. But how convincing was the argument that *P. cinnamomi* is native and, whatever its origins, how big a threat is it to native vegetation here?



Patch death of Corymbia gummifera *and* Allocasuarina littoralis *at Beecroft Peninsula (Jervis Bay). Most understorey shrubs have also died (especially* Banskia ericifolia*) and the site is now dominated by sedges. There has been extensive soil sampling in around the patch and* P. cinnamomi *can only be isolated from the area showing symptoms. Photograph: K. McDougall*

Pratt and Heather (1973) and Pratt *et al.* (1973) argued that *P. cinnamomi* was not introduced into eastern Australia following European settlement because: 1) it was so widespread; 2) it had been found in a remote, apparently undisturbed area; and 3) the native flora shows considerable resistance to disease symptoms suggesting a long association with the pathogen.

Recent genetic and molecular evidence, however, indicate that there are low levels of genetic diversity in Australian populations (both on the west coast and east coast), which is consistent with an introduced organism and rarely seen in active, widespread indigenous organisms (Linde *et al.* 1999; Dobrowolski *et al.* 2002). The isolation of *P. cinnamomi* in soil from a remote part of the Budawang Range of south-eastern NSW (reported by Pratt *et al.* 1973) also does not mean that the pathogen pre-dates European settlement. Logging, cattle grazing and gold prospecting had occurred in the catchment of the Budawang Range sampled by Pratt (Pratt *et al.* 1973; Routley and Routley 1974).

The current evidence does not prove that *P. cinnamomi* was recently introduced into NSW. It does strongly suggest that this is the case though, and there is certainly no proof to the contrary. Absolute proof may be impossible to achieve but the argument is somewhat esoteric and irrelevant in a management context. Even if *P. cinnamomi* were native on the east coast of Australia, it could still be regarded as a pest requiring action. There are many examples of native Australian plants becoming pests when management regimes or agricultural practices have altered the landscape and favoured some organisms that would not be favoured under natural conditions. The relevant question about *P. cinnamomi* in eastern Australia is not whether it is native or introduced but whether it is having an adverse impact on ecosystems that are regarded as having biodiversity, cultural or economic value.

A detrimental impact from *P. cinnamomi* in NSW should not be surprising as the pathogen has been recognised for some time as the cause of occasional but significant patch death in *Eucalyptus sieberi* forest on poorly drained sites

in eastern Victoria (Marks and Smith 1991). Soil pathogens have no regard for state boundaries and the *E. sieberi* forests in the Eden area of NSW also bear the scars of infestation. Symptoms are rarely observed in canopy species, however; the impact is closer to the ground and extreme in areas with a diverse shrubby understorey. Infestations are characterised by patches of dying and dead plants of *Xanthorrhoea australis*. Deaths of understorey shrub species (eg. *Acacia terminalis*, *Banksia serrata*, *Daviesia wyattiana*, *Epacris impressa*, *Pultenaea daphnoides* and *Tetratheca subaphylla*) are common. Following infestation, the vegetation appears to change from a forest with a diverse shrubby understorey to a forest with a largely herbaceous understorey dominated by monocots such as *Lomandra confertifolia* and *Tetrarrhena juncea* (McDougall and Summerell 2003*b*). The endangered Smoky Mouse, which uses the shrubby understorey and feeds on seeds of many of the species susceptible to infection, is at great risk as a consequence. So too may be the endangered mallee, *Eucalyptus imlayensis*, which is restricted to about 80 individuals near the summit of Mt Imlay. Several plants have died in the past five years and, although an association between death and *P. cinnamomi* has not yet been established, deaths of other species adjoining the site are certainly attributable to the pathogen.

Because of the long-held belief that *Phytophthora cinnamomi* is a native of eastern Australia and the focus of past field observers on tree health (rather than understorey health), I believe many of the impacts of this pathogen have gone un-noticed. We are now sadly in a position of ignorance as we attempt to deal with this threat. The following pieces of the puzzle are available:

- Numerous plant deaths were caused by *P. cinnamomi* in dry sclerophyll forests on Black Mountain (Australian Capital Territory) in the wet summer of 1970-71 (Taylor 1974) but there have been no major impacts reported since.
- In other parts of south-east NSW, *P. cinnamomi* appears to be the cause of patch death in understorey species in *Eucalyptus dalrympleana* forest near Brown Mountain, in *Corymbia maculata* forest near Batemans Bay and in *Eucalyptus botryoides* / *E. baxteri* woodland and adjoining heathland at Green Cape (McDougall and Summerell 2003*b*).
- On the Central Coast of NSW, *P. cinnamomi* may be the cause of or be contributing to the decline of *Xanthorrhoea resinifera* in heathland in Royal National Park. The pathogen has also been implicated in the extensive canopy death of *Angophora costata* on the shores of Sydney Harbour (Summerell 2002) and the more localised patch death in heathy *Corymbia gummifera* woodland in Jervis Bay (Howard *et al.* 2004).
- On the Northern Tablelands, significant infestations of *P. cinnamomi* causing deaths of native species have been identified in *Eucalyptus pauciflora* woodland in Barrington Tops National Park (McDougall and Summerell 2003*a*) and in heathland and *E. andrewsii* subsp. *campanulata* woodland in Werrikimbe National Park (McDougall and Summerell 2003*b*). At the Barrington Tops infestation there has been a clear change in the understorey from vegetation dominated by dense shrubs (the remains of which are still present) to vegetation dominated by grass (*Poa sieberiana*). *Tasmannia purpurascens,* a shrub that is listed as vulnerable under the State and Commonwealth threatened species legislations, appears to be especially susceptible to infection. *Xanthorrhoea glauca* subsp. *glauca* populations in Werrikimbe National Park are severely affected and at least one (comprising hundreds of plants to 300 years of age) is likely to become extinct in the coming decades (McDougall and Summerell 2003*b*).
- An association between plant death and *P. cinnamomi* in coastal heathland in south-eastern Queensland was reported more than 30 years ago (Pegg and Alcorn 1972) but there appear to have been no reports of *P. cinnamomi* related plant deaths there since.
- Canopy dieback related to infection of trees by *P. cinnamomi* is widespread in tropical forest between Cardwell and Mossman in Queensland (Worboys *et al.* 2003). *P. cinnamomi* has been isolated from the roots of several dying rainforest trees, including species of 16 genera and two families not previously known to be hosts of the pathogen (Brown 1999).

The emerging evidence of the impact of *Phytophthora cinnamomi* in eastern Australia raises some intriguing questions. Whilst some of the impacts are not surprising based on our knowledge of susceptibility from other states (eg. deaths of *Xanthorrhoea* species and some peas and epacrids), trees such as *Angophora costata* and *Corymbia gummifera* have been identified in the past as resistant to infection and suitable for planting into infested areas (Edmiston 1989). At the sites where these species are dying there is good evidence for a link between death and the presence of *P. cinnamomi* (Summerell 2002, Howard *et al.* 2004) so it is not simply the case that the blame has been attributed to the wrong cause (although in both cases there may be other factors at work). Is *P. cinnamomi* operating differently in eastern Australia to southern and western infestations? If two reputedly resistant trees are affected here, could *P. cinnamomi* be contributing to other malaise such as Bell Miner Associated Dieback (BMAD Working Group 2004), for which it has not been a consideration previously? There is so much we don't know about *P. cinnamomi* in eastern Australia. It is time, however, for us to move on from our past beliefs about the origin of *P. cinnamomi*, and focus on finding out more about what is vulnerable in eastern Australia, how the pathogen is operating here and how we can deal with it.

Almost half of this population of Xanthorrhoea glauca *subsp.* glauca *at Werrikimbe National Park was found to be dead or dying in 2002 and deaths are continuing.* Phytophthora cinnamomi *has been isolated from the roots of the dying Xanthorrhoeas and other species. There are very few young plants in the population and some are estimated to be 300 years old based on stem ripples. Without recruitment this population is likely to become extinct in the coming decades, greatly changing the character of the vegetation. Photographer: B. Summerell, Royal Botanic Gardens Sydney*

Evaluating the impact and threat of *P. cinnamomi* in eastern Australia

If *P. cinnamomi* is a threat to vegetation in eastern Australia but we know precious little about it here, how does one judge whether vegetation is being affected by *P. cinnamomi* and how does one manage sites and activities to minimise the threat? These are fair questions and not easy to address.

In assessing whether a site is being affected by *P. cinnamomi*, it is worth considering the following matters in the order presented:

- Are there unhealthy or dead plants present for which no explanation can be found? Fire is often the cause of dead stems and, in some species, these will persist long after the vegetation has regenerated. If there are no dead and sick plants, *P. cinnamomi* may still be present but not causing a noticeable impact on the site.
- Is the site vulnerable to impacts from *P. cinnamomi*? Areas with a mean annual temperature of < 15^{o}C, mean annual rainfall of < 600 mm, or on limestone-derived soils are unlikely to be affected by *P. cinnamomi*. Some wet sclerophyll forest on the Great Dividing Range also appears to be at low risk, perhaps because of the suppressive properties of the soil (Halsall 1982).
- Are susceptible species present and are these the ones dying or in poor health? A list of species known to be susceptible to infection (and those that are field resistant) will be available soon (http://www.cpsm.murdoch.edu.au/). The list is not definitive; i.e. the species listed as susceptible will not be susceptible in all circumstances and many susceptible species are probably not listed. The list might however be used as an indication of a possible link between *P. cinnamomi* and poor species health.
- Is *P. cinnamomi* present? Diagnostic services are available to test for the presence of *P. cinnamomi* (eg. Royal Botanic Gardens Sydney). It is important to consider the time of year when soils are collected (this should be when soils are moist and warm) and the number of samples required to maximise the probability of detection. The diagnostic service will be able to provide advice on sampling procedure and intensity.
- Can a link be made between the poor health of plants and the presence of *P. cinnamomi*? This is really the key step but the most difficult to achieve. *P. cinnamomi* will be present for a short time in the roots of susceptible species, often when they show few symptoms. This root material can be tested by the same diagnostic services that test soil. If *P. cinnamomi* can be consistently isolated from root material of species showing symptoms, there is a strong case for it being the cause of or contributor to those symptoms. In the case of large trees it will often be impossible to locate infected root material as only a small proportion of roots may be infected (but still cause symptoms) and roots are often deeply buried. In such cases, circumstantial evidence of a link may be obtained by testing soil of symptomatic and asymptomatic areas of similar vegetation. If *P. cinnamomi* can only be located in symptomatic vegetation there is reason to suspect that it is contributing to the malaise. This was the initial approach used with apparent infestations in *Angophora costata* and *Corymbia gummifera* forests mentioned above.

How best to manage for *P. cinnamomi* in eastern Australia? There are some assumptions and basic principles that may be applied despite our ignorance.

- *P. cinnamomi* is widespread in the coastal strip of south-eastern Australia. Most activities will be in or close to infestations (in which there may be no outward signs of its presence).
- Activities that involve major soil disturbance should contain the disturbance to the site of the disturbance where possible, but at the very least avoid taking soil to areas where *P. cinnamomi* may have an impact (see the next point).

- The importation of soil and gravel to an area likely to be vulnerable (eg. those on the coast and escarpment with threatened species, heathy vegetation or species known to be susceptible) should be avoided unless the area is already infested.
- In general, the movement between sites of clods of soil on vehicles and shoes should be avoided (as these may contain weeds as well as pathogens).
- Sites containing dead and dying plants where there is no obvious reason for the symptoms should be treated as though they are diseased (by *P. cinnamomi* and/or other pathogens) and plant and soil material not removed and taken to other areas.
- Record keeping for apparently affected sites is recommended. This can often be easy and extremely useful. For example, managers might a) mark the boundaries of areas showing symptoms (to allow an assessment of whether and how fast the malaise is spreading); b) list species being affected; c) photograph sites; d) set up floristic monitoring plots. An important step in the fight against *P. cinnamomi* in NSW will be the establishment of a single repository for such records and other information about this pathogen.

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Control of *Phytophthora cinnamomi* with phosphite: some recent developments in application methods

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Phytophthora cinnamomi has a world-wide distribution, causes disease in a very wide range of plants and is responsible for the destruction of certain plant communities in Europe and Australia. *P. cinnamomi* was probably introduced into Australia in the nineteenth century and is now established in south-western Australia and Tasmania, and throughout eastern Australia, from South Australia to the wet tropics. *P. cinnamomi* is listed as a Key Threatening Process under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999.*

Apart from quarantine and hygiene, chemical control is used in horticulture, and to a limited extent in natural ecosystems, to control *P. cinnamomi.* In contrast to contact fungicides, phosphite (neutralised phosphorous acid) is a systemic fungicide that, in part, potentiates plant defence mechanisms so that there is a more rapid and robust response to the pathogen. Phosphite can be applied as a low volume aerial spray, high volume foliar spray, or by trunk injection of individual plants. A summary of application protocols used in the treatment of native vegetation, including recommended application rates, is available at www.calm.wa.gov.au/projects/pdf_files/dieback_phosphite_manual.pdf. In comparison with other treatment methods, trunk injection provides the longest protective effect (up to five years) and is most economical in the use of phosphite, but is also labour intensive.

At the Centre for *Phytophthora* Science and Management (CPSM) at Murdoch University, we have initiated some experiments aimed at enhancing the efficacy of phosphite in the control of *Phytophthora*. Recently, the Garbelotto laboratory (University of California at Berkeley; http:www.cnr.berkeley.edu/garbelotto/) has demonstrated the efficacy of an oganosiloxane ultra-penetrant that enables uptake of phosphite applied directly to the trunk of the tree (basal bark application—BBA—tested on oaks against *Phytophthora ramorum*). We have conducted a series of experiments with *Banksia* spp. and *Eucalyptus marginata* (Jarrah) to further test the efficacy of BBA in some Australian species. Phosphite, diluted to 200 grams per litre active ingredient, was mixed with the organosiloxane (Pentra-Bark™, Agrichem Manufacturing Industries P/L) at 2.5% (by volume). The mixture was applied to just before runoff to the entire circumference of the trunk to 2.5 m above ground level with a knapsack sprayer. Stem inoculation with an aggressive isolate of *P. cinnamomi* was used to assess the level of protection, in comparison with untreated trees, and trees treated by injection and low volume foliar spray.

*Basal bark application of phosphite to Jarrah (*Eucalyptus marginata*).*
Photograph: Emma Groves, Murdoch University

Key outcomes were:

- Basal bark application (BBA) of phosphite was at least as effective as other treatments in protecting *Banksia* spp. against *P. cinnamomi*.
- BBA with phosphite at 70 $g^{-1}l^{-1}$ (one third of the standard rate) was equally effective as the standard treatment (tested only in one season with *Banksia menziesii*).
- BBA treatment was ineffective in Jarrah. Foliar analyses showed limited uptake of phosphite in BBA treated trees.
- Mean foliar phosphite concentrations in BBA-treated banksias were 10 to more than 100 fold those of other treatments, with few signs of phytotoxicity.
- For similar sized trees, the application time for BBA treatment was approximately one third of that required for treatment by injection.

Apart from a reduction in application time, if increased concentrations of phosphite in plant tissues translate to an increase in the period of protection, then BBA treatment may prove to be a cost effective method of protecting individual plants against *Phytophthora.*

With the aim of eliminating spot infections of *Phytophthora cinnamomi*, we also tested the efficacy of soil drenches of phosphite (up to 1700 grams of active ingredient per square metre) in artificially infested forest and rehabilitated mine site soils, in spring and autumn. In the soil types tested, phosphite drenching suppressed but did not eliminate *P. cinnamomi.*

It should be noted that the treatment methods described in this article are off-label and may require authorisation under state or Commonwealth legislation.

Guns, germs and fill: the role of the Harbour Trust in addressing harbour foreshore dieback

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The Sydney Harbour Federation Trust (Harbour Trust) was set up by the Commonwealth Government to conserve and restore seven historic Commonwealth sites around Sydney Harbour with a charter to return these lands to the people. Central to the Trust's role is to plan for the future of these sites in a way that maximises public access and preserves their cultural and natural heritage. The lands were previously used for military service, maritime industries or special purposes, and were closed to the general public for more than 150 years. The sites include the former School of Artillery, North Head; military lands at Georges Heights, Chowder Bay and Middle Head, Mosman; Woolwich Dock and Parklands; Cockatoo and Snapper Islands; the Macquarie Light Station, South Head; and the former Marine Biological Station, Vaucluse. The sites have significant natural and cultural heritage values that are matched by considerable management challenges, including soil contamination, aging infrastructure and ecological stress. The Harbour Trust has a ten year life span to restore these sites and open them up for public access and recreation.

This article focuses on one aspect of the Harbour Trust's work; the management of vegetation dieback in bushland areas of Middle Head, Georges Heights and Chowder Bay in the Northern Sydney suburb of Mosman. The article also discusses the role of the Sydney Harbour Dieback Working Group in working towards best practice management of dieback among key local, state and Commonwealth land managers in the lower North Shore area of the Sydney Harbour Catchment.

The Trust's lands at Mosman have a long history of military use dating back to the early 1800s, and are generally up-hill from former military lands that now form part of the Sydney Harbour National Park (managed by the NSW Department of Environment and Conservation, Parks Division). When the Harbour Trust took over these former military lands in 2000-2002, the remnant sandstone bushland that makes up approximately half of the area had already survived a long history of disturbance and fragmentation due to early land clearing, followed by construction of roads, barracks, forts, tunnels and service utilities. As with most of Sydney's urban bushland, incremental development has brought severe stresses to the sandstone heaths, woodlands and forest vegetation communities of the harbour foreshores, leading to loss of habitat and biodiversity. These stresses include altered soil chemistry and hydrology due to an influx of urban stormwater laden with nitrogen, phosphorous and

other contaminants, promoting a dominant weed understorey at the expense of native regeneration. Other stresses include the absence of fire for many decades, leading to a dominance of 'mesic' species. These are generally 'soft' leaved plants (like *Pittosporum undulatum*, *Cissus antarctica* and *Glochidion ferdinandi*) adapted to higher moisture and shade levels than sclerophyllous plants that are generally hard-leaved and/or spiky (adapted to drying out and sun/wind exposure). With absence of fire increased stormwater and nutrients in a lot of urban bushland, some vegetation communities are changing from a floristically rich sclerophyllous assemblage to a floristically poor mesic assemblage. Other changes and stresses include a simplified vegetation community, and predation of native flora and fauna by introduced animals such as rabbits, cats and foxes.

*View of dieback-affected Angophoras (*Angophora costata*) at Middle Head. Photograph: Peter Jensen.*

Dieback of native trees has been noticed around the northern foreshores of Sydney Harbour since at least the 1970s, with several studies into the causes having been conducted since. An historical air photograph survey carried out by the Harbour Trust and the NSW National Parks and Wildlife Service (NPWS) in 2003 identified vegetation change along drainage lines around Georges Head and Middle Head, dating back to about 1965. This change has become extensive with many hundreds of *Angophoras* (*Angophora costata*) and Bangalays (*Eucalyptus botryoides*) dying in these areas, most noticeably at Middle Head where groves of skeletonised trees haunt the rugged landscape. A forum of concerned local environmentalists and technical experts met in 1979 to discuss the causes of dieback of trees around the harbour. Various possible causes were put forward, including the possible impact of wind-blown surfactants emanating from the North Head sewage treatment plant (prior to the construction of the deep ocean outfall). Other possible causes included drought, insect predation, air pollution and stormwater nutrient influx. The little known root-rot pathogen *Phytophthora cinnamomi (Pc)* was briefly mentioned as another. However it was not until 2000 that *Pc* was first positively identified in soil sampling of dieback-affected *Angophora* forest at nearby Cremorne Point, in the North Sydney Local Government Area. More recently, in 2002, testing carried out by the Royal Botanic Gardens (RBG), Sydney confirmed that *Pc* was active across the Middle Head/Georges Heights landscape.

The Harbour Trust recognised the seriousness of the issue when it took possession of the Defence lands at Middle Head in 2001. With the identification of *Pc* across the lands in 2002, the Trust began a program of more extensive *Pc* testing while taking a risk-based approach to management, including:

- adoption of *Pc* hygiene protocols for contract bush regenerators and bushcare groups;
- stormwater improvements on the lands to reduce nutrient loads and reduce peak flows to bushland;
- consideration of *Pc* management in the design and implementation of new walking tracks; and
- community education.

As a further response the Trust, together with the ANPC; RBG, Sydney; Australian Association of Bush Regenerators (AABR); and NPWS hosted a forum on the issue in September 2003, bringing together interested stakeholders including local government bushland managers, community-based bushcare groups and local environmentalists. The forum of 120 participants was addressed by local land managers and scientists working on *Pc*-induced dieback in other parts of NSW and Western Australia. One of the key outcomes of the forum was the establishment of the Sydney Harbour Dieback Working Group based on a model of working groups set up in *Pc* infected Jarrah forests of WA. The group has met quarterly since late 2003 to help coordinate management of dieback across land tenures and raise awareness of the issue among the general public.

Achievements of the group have included the broad scale adoption of *Phytophthora* hygiene protocols for bush regenerators and contractors working in bushland, based on those developed by Professor Brett Summerell of the Royal Botanic Gardens, Sydney. These protocols, along with *Pc* testing, site specific signage, disinfectant footbaths, *Pc* affected soil management and work-site control points have been introduced as part of major civil works being carried out by the Harbour Trust to mitigate against the spread of *Pc* to uninfected areas. New walking tracks, such as the Middle Head to Balmoral Boardwalk, have been designed to allow minimal contact with soil and boot scraping stations are sited at track entry and exit points. Stormwater drainage is being improved at Lower Georges Heights by removing pollutant sources (for example by repairing drainage systems and carrying out site remediation), re-designing stormwater to retain and direct water away from bushland, and the construction of bioswales.These are ephemeral constructed wetlands aimed at capturing high flows of stormwater, reducing velocity of overland flow and releasing water through infiltration and gradual release to natural drainage lines. They are planted with native water plants to help take up nutrients and provide habitat for native fauna.

Another initiative of the group is the program of soil sampling and *Pc* mapping with support from the University of Sydney's Centre for Precision Agriculture under the direction of Professor David Guest and Dr Rose Daniel. The university has taken on the collation of data on behalf of the working group to gain a better picture of the occurrence of *Pc* across the landscape. The Harbour Trust, Taronga Zoo, NPWS, Mosman, Manly, North Sydney and Willoughby Councils have also commenced trials of tree injection with potassium phosphonate (phosphite) on *Angophora costata*, *Eucalyptus botryoides*, *E. piperita* and *Corymbia gummifera*. This approach has proven successful in reducing the impact of *Pc* on species in Western Australia. The Harbour Trust has also initiated a program of half-yearly photographic monitoring of injected trees by a local bushland volunteer to monitor the effect of the phosphonate. Data gathered at time of injection includes GPS location, projective foliage cover, signs of epicormic growth, insect herbivory, aspect and weather conditions.

The Harbour Trust and several land managers are preparing interpretive signage to raise awareness of *Pc* along tracks and bushland entry points. The group has worked together to produce an educational brochure and poster on dieback and *Pc* that is made available to the general public on walking tracks, council information stands, and through local bushcare networks. The Working Group is also developing a strategy document to guide the coordinated management of land managers over the coming years. The issue of vegetation dieback and the role of *Pc* in the urban area raises many questions about practical land management and the challenge to find a comprehensive solution remains.

More information about the Harbour Trust and the dieback issue can be found at www.harbourtrust.gov.au

*Harbour Trust volunteers injecting Bangalays (*Eucalyptus botryoides*) with phosphite at Middle Head. Photograph: Peter Jensen.*

A thief of time: *Phytophthora cinnamomi* and threatened flora

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Diversity 'hot spot' in danger

Since time immemorial a great diversity of plants has been evolving in Western Australia. The unique flora of south-western Australia is of international importance because of the high degree of richness and endemism and the high proportion of the flora at risk from threatening processes (Atkins 1998). Of the 5710 species currently known for the South-West Botanical Province, 79% are endemic to the region (Paczkowska and Chapman 2000). Western Australia has about 8% of the world total of threatened, rare and poorly known flora, making the state one of the major centres for threatened flora in the world (Atkins 1998).

Diversity destroyer: the 'biological bulldozer'

Popularly known as the biological bulldozer (WWF Australia and Dieback Consultative Council 2004), the introduced pathogen *Phytophthora cinnamomi* is a major threatening process affecting the viability and genetic diversity of the flora of south-western Australia (Shearer 1994; Brown *et al*. 1998). The pathogen has been recognised as a 'key threatening process' under the Australian Government's *Environment Protection and Biodiversity Conservation Act 1999*. Shearer *et al*. (2004) estimated from four databases that 2284 species of the 5710 described plant species in the South-West Botanical Province are susceptible to *P. cinnamomi* and 800 of these 2284 species are highly susceptible to the pathogen. They concluded that "*P. cinnamomi* in south-western Australia is an unparalleled example of an introduced pathogen with wide host range causing great irreversible damage to a range of unique, diverse but mainly susceptible plant communities". The clock cannot be turned back on infested plant communities because *P. cinnamomi*-mediated plant death irreversibly reduces community composition, structure and function. Time is running out for threatened flora in diseased areas, as *P. cinnamomi* infestation can ultimately result in plant species extinction.

Conserving diversity

As part of the efforts to gain some time, the Department of Conservation and Land Management's Threatened Flora Seed Centre conserves seed of threatened Western Australian native plant species. Plant species targeted for long-term seed conservation include plants that are restricted in their geographic range or whose habitat is threatened by a variety of processes such as land clearing, disease, grazing, salinity and weed invasion (Cochrane and Coates 1994). This collection is a dynamic one, and in addition to seed conservation, the collection also tests plants for susceptibility to *P.cinnamomi* (Cochrane 2001).

Figure 1: Threatened Banksia brownii. *(a) Healthy plants. (b) Few plants remain alive, 45 days after soil inoculation with* Phytophthora cinnamomi. *Dead plants have been removed to show remaining live plants. Photograph: Bryan Shearer*

Epidemic in a pot

Although 40 years have elapsed since the discovery of the association between *P. cinnamomi* and plant deaths in south-western Australia, host susceptibility is poorly understood and host lists are not extensive. At the Threatened Flora Seed Centre routine germination tests are conducted on all seed targeted for long-term conservation. If the resulting germinants are not needed for species translocation efforts or other studies, they are tested for *P. cinnamomi* susceptibility. This is done by mimicking epidemics of *P. cinnamomi* in pots. Under warm moist conditions in a shadehouse, pieces of wood infested with *P. cinnamomi* are inserted into the pots containing at least 6-month-old seedlings. The infested pieces of wood simulate roots infected with *P. cinnamomi,* from which the pathogen sporulates and infects the roots of the threatened flora. In

susceptible taxa, *P. cinnamomi* grows up the roots forming collar lesions that kill the plant. Plant mortality is followed over time and susceptibility assessed. Figures 1 and 2 show death of threatened *Banksia brownii* and *Dryandra montana,* 45 days after *P. cinnamomi* soil inoculation. To date we have tested 552 accessions for *P. cinnamomi* susceptibility.

Figure 2: Threatened Dryandra montana. *(a) Healthy plants. (b) Few plants remain alive, 45 days after soil inoculation with* Phytophthora cinnamomi. *Photograph: Bryan Shearer*

Outcomes

This testing allows us to rank the taxa according to *P. cinnamomi* susceptibility, thereby prioritising threatened flora according to hazard from the pathogen. It also reveals the variation in susceptibility within and between families. Such information can be used to interpret differences in survival of threatened flora under different situations and assist in studies on mechanisms of resistance. This study of variation in susceptibility also enables the identification and selection of resistant individuals within susceptible taxa. How within-species variation in susceptibility can best be used in the long-term management of threatened flora populations needs to be a high research priority.

Prognosis

Significant progress has been made towards developing and applying hygiene procedures aimed at stopping new infections and spread of the pathogen. Hygiene procedures are delaying tactics and work best when integrated with methods of control that reduce the rate of *P. cinnamomi* development. One such method of protecting threatened flora is the aerial application of the systemic fungicide phosphite (Shearer and Fairman 1997; Barrett 2003). Further work is required to optimise phosphite prescriptions for best protection. Current methods of disease management are holding actions and the development of alternate methods of control must be a high research priority. During the time elapsed while you have been reading this article, *P. cinnamomi* - induced extinction mechanisms have pushed more plants to the edge of oblivion. Time is running out for *B. brownii* and *D. montana* (Figures 1 and 2), as *P. cinnamomi* has the potential to extinguish these and similar threatened plant species from the face of the planet.

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Conservation of flora and plant communities threatened by *Phytophthora* dieback in southern Western Australia

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Dryandra montana*, one of only 45 remaining plants. Photograph: Greg Freebury*

The South-West Botanical Province of Western Australia is an internationally recognised Biodiversity Hotspot due to the number of endemic species under threat (Myers *et al*. 2000). Contained within the SW Province are several botanical hotspots in terms of species richness and or endemism (Hopper and Gioia 2004). Notable among these are the Mt Leseur area, the Swan Coastal Plain, and in the South Coast region, the Stirling Range and Fitzgerald River-Ravensthorpe Range area. However, over many years a biological disaster has been played out in some of these species-rich shrublands, particularly in higher rainfall areas and on water-gaining sites. Dieback caused by the soil-borne water mould *Phytophthora cinnamomi* has killed susceptible species over vast areas where climate, soils, topography and rainfall provide conditions ideal for the survival, sporulation and dispersal of the pathogen. These shrubland communities are dominated by susceptible members of the Proteaceae, Papilionaceae and Epacridaceae families. Death of these species as a result of infection by *P. cinnamomi* has significantly changed plant community composition and structure with up to 50% loss of vegetation cover in affected areas (WWF Australia and Dieback Consultative Council 2004). Recent research has estimated that some 40% of the 5710 described plant species in the South-West Botanical Province are susceptible to *P. cinnamomi* while 14% are highly susceptible (Shearer *et al*. 2004).

The impact of *Phytophthora* dieback on biodiversity has been particularly serious in areas rich in localised endemics such as the Stirling Range National Park north of Albany. Some two-thirds of the Stirling Range National Park is considered to be infested by the pathogen. The park currently contains 27 flora species listed as nationally threatened; 18 of these are endemic to the Stirling Range while19 are currently affected by *Phytophthora* dieback. However, with more than 80 endemic species in total, many of which are poorly known taxa, *Phytophthora* dieback threatens considerably more species with extinction. At present, ten Stirling Range taxa have critically endangered status. Species such as *Dryandra montana* (Mountain Dryandra) see image above, *Lambertia fairallii* (Fairall's Honeysuckle) and *Dryandra anatona* (Cactus Dryandra) have already undergone population extinctions in recent years. With only 46 surviving mature plants, *Dryandra montana* is currently at greatest risk of extinction. In Cape le Grand National Park east of Esperance, *Lambertia echinata* ssp. *echinata* (Prickly Honeysuckle) has less than 75 mature plants surviving in a landscape similarly affected by *Phytophthora* dieback. In the Busselton Ironstone community in the southern Swan Coastal Plain, only 60 plants of *Lambertia echinata* ssp. *occidentalis* (Western Prickly Honeysuckle) survive.

Several threatened ecological communities (TECS) are also threatened by *Phytophthora* dieback; these include the Nationally Threatened Eastern Stirling Range Montane Thicket community and the Montane Mallee Thicket of the Stirling Range. All occurrences of the former have been modified by *Phytophthora* dieback, with few Proteaceous species remaining in a community once rich in *Banksia* and *Dryandra* species. Some 70% of the Montane Mallee Thicket is infested with an incremental loss of habitat

annually. The mountainous terrain of the Stirling Range has contributed to greatly increased rates of spread with entire hillsides rapidly succumbing to the pathogen. Other plant communities affected by *Phytophthora* dieback on the list of TECs endorsed by the WA Minister of the Environment include the Nationally Threatened Busselton Ironstone community, *Banksia* woodland communities on the Swan Coastal Plain and the Mt Lindesay granite complex near Denmark.

Arresting the threat

As there is currently no method of eradicating *Phytophthora*, all efforts must be made to limit the spread of the disease from infested to non-infested sites. Strategies used to prevent transfer of soils between sites include seasonal closure of roads and walking trails, signage and hygiene measures to ensure vehicles are clean and providing boot cleaning stations on walking trails. In areas of high conservation value permanent closure of roads and trails may be necessary. It is important to identify areas of bushland that are currently healthy but extremely vulnerable if *Phytophthora* dieback were to be inadvertently introduced. These may include once common plant communities such as *Banksia coccinea* (Scarlet Banksia) shrublands, *Banksia speciosa* (Showy Banksia) or *Banksia attenuata* (Candle Banksia) woodlands. While the Stirling Range National Park has been significantly modified by *Phytophthora* dieback, the species-rich Fitzgerald River National Park (with some 1750 species) remains predominantly healthy. However, one infestation in the centre of the park threatens adjacent plant communities. Even with hygiene and quarantine measures in place, *Phytophthora* dieback will continue to spread autonomously from this infestation.

Faced with this biological disaster, in the mid-1990s researchers at WA's Department of Conservation of Land Management (CALM) developed techniques for the application of the fungicide phosphite, used successfully in horticulture, to native plant species and communities in Western Australia (Hardy *et al*. 2001). Since 1997, aerial phosphite applications have been conducted by CALM to spray threatened plant communities and flora affected by the disease. While phosphite does not eradicate *P. cinnamomi* it does boost plant defence mechanisms, thereby increasing the resistance of susceptible species to the pathogen. Monitoring of flora sprayed with phosphite annually or biannually has shown that the survival of susceptible species has been improved at many, if not all, sites. This has 'bought' time to proceed with other conservation measures such as collection of seed and germplasm for *ex situ* conservation. Translocations have been implemented in recent years for several species threatened by *Phytophthora* dieback, including *Lambertia occidentalis,* while a seed orchard has been recently established for *Dryandra montana*. These measures may provide an opportunity to restock depleted populations *in situ* in the future.

Further research is still required to fine tune phosphite applications. Species may vary in their response to the chemical while application techniques may vary in their efficacy. Trunk injection may be particularly effective, giving control for up to five years (Shearer *et al*. 2004). Further research is also required to fully understand the epidemiology of the disease in shrubland communities in the south coast region of WA and to explore other methods of containing the 'biological bulldozer'.

Aerial application of the fungicide phosphite to control Phytophthora *dieback. Photograph: Malcolm Grant*

Acknowledgements

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Managing *Phytophthora cinnamomi* on a rare ironstone multi-translocation site in Western Australia

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This previously mined area, originally comprising farmland as well as some small pockets of remnant bushland, was reworked after the cessation of mining to remove and reposition sand tailings, treat the sulphide soils and create a contoured landscape as well as many lakes for wildlife habitat. A visit to the site in 2002 during earthworks indicated that the nationally vulnerable *Grevillea brachystylis* subsp. *australis* was present on site. These populations were immediately protected by the site owners BHP Billiton and reported to the Department of Conservation and Land Management (CALM) who are responsible for the protection of the state's flora. Permission was sought to remove some of the plants in line with earth moving operations and seed was gathered from these plants to retain genetic material. Discussions were held with Kings Park and Botanic Garden about a one-year research proposal and pilot study involving translocation. Due to the rarity of ironstone sites and the presence of a number of other threatened species close by it was decided to attempt a 'multiple translocation' involving the following threatened ironstone species: *Darwinia ferricola*, *Dryandra nivea* subsp. *uliginosa*, *Grevillea brachystylis* subsp. *australis* and *Lambertia orbifolia* subsp. 'Scott River Plains'. A site was chosen where plants could become established and self sustaining. Though *Phytophthora* is known to occur in the area there was no indication that root pathogens were on this site. However, it seems that *Phytophthora* entered the site through surface water runoff via streams. In this article I explain our strategy for controlling *Phytophthora* in the translocation site.

Site preparation and planting

The host site, which lies over a solid ironstone base, was prepared by importing (from another part of the mine site) two soil types, grey free draining sandy soil and red/brown sandy loam, both from *Phytophthora* free areas. Soil was spread as level as possible to a depth of about 10 cm. Although the threatened species require high water tables, to avoid flooding the site the winter high water level was designed to be 30cm below soil level. The site was divided into irrigated (2 litre/hour in-line drippers at 1m intervals) and non-irrigated sections and fenced with wire netting to prevent grazing by rabbits.

All plants used in the translocations were raised in Kings Park under 'Nursery Accredited Conditions' to reduce the risk of introducing root pathogens to translocation sites. The winter plantings experienced a hail storm one week after planting, shredding many leaves, and were also subject to wind blown sand which covered many plants completely.

Lambertia *showing signs of* Phytophthora *attack. This is a good stage to dig them up for testing. Photograph: Bob Dixon*

Managing the site

Despite the hostile growing conditions, i.e. an open area with constant wind and poor soils, the plants responded very well. All the species are adapted to growing over ironstone with their roots finding fissures enabling them to grow down to the water table. Due to the normally regular rainfall in this area the irrigation is only turned on during long dry periods. Luckily weeds find it difficult to grow in these conditions, therefore the weed control programme consists of careful spot spraying using glyphosate. The site is checked on a regular basis by BHP Billiton staff and monitored twice a year by Kings Park staff for survival and growth rates as well as flowering, seed production and pest/disease attack (more frequent monitoring is difficult as the site is a three and a half hour drive from Perth).

Controlling pathogens

After a few *Lambertia* plants started to die on site they were immediately and carefully dug up to avoid spreading any disease and sent to a disease testing centre specialising

in root pathogens. Due to a time delay in obtaining the test results we immediately sprayed for canker disease, a well known pathogen of this species. The test results indicated the main pathogen was *Phytophthora*, with some secondary infection by *Pythium* sp. On seeking specialist scientific advice as well as advice on field application, a half strength rate of Sprayfos 400 (400g/L phosphorus—phosphonic acid, usually referred to as phosphite) was used at a rate of 2.5 ml/L water, plus Agral 600 at the rate of 3 ml/L water. Application was by a backpack sprayer spraying to run off.

Treatment with phosphite has been found to be ineffective on some species of *Lambertia*, eg *L. inerms*, but *L. orbifolia* subsp. Scott River Plains had not been tested (B Shearer pers comm.).

To catch the most active time of the disease, moist warm conditions, the phosphorous is applied twice a year in early April and October. Results to date indicate the phosphite treatment is working very well with only one more plant dying, and this may not even be attributed to *Phytophthora*. The use of phosphite is not simple; it can cause some problems, for example it is known to reduce flowering/seed production in some species. To assess what may happen after spraying, seed of the first species to flower, *Grevillea brachystylis ssp australis,* was collected. Viability tests (cut test) were carried out and these indicated 98% viability. We also treated the seeds with smoke water (the usual treatment for this species), and sowed them in a constant 18 degree centigrade temperature. To date only a few seedlings have germinated and in line with usual practice, these were removed from the cool room as soon as they started to germinate. Further germinants did not appear so the seed tray was put back in the cool room and a few more seeds are starting to germinate. Two more lots of the same seed batch have also been sown. However, fresh seed will be collected again this autumn and we will repeat our original germination trials to compare these treatments. Seed from other species will also be collected, when appropriate, to test their viability too.

Managing this site has been a team effort through the dedication and assistance of the BHP Billiton site staff, Kings Park (Botanic Garden and Parks Authority) staff and many volunteers, in particular Kings Park Master Gardeners who help with label making, work on site and data entry. BHP Billiton are continuing to support this project.

Site at Oct 2003 showing two soil types, trickle irrigation system and non irrigated area. Photograph: Bob Dixon

Site as at 1 April 2005. Dryandra nivea *subsp* uliginosa *(foreground) and* Darwinia ferricola *(rounded shrub). Photograph: Wendy Cusack*

Future predictions

We believe that as long as the site continues to be managed as it is at present the translocated plants will continue to grow well, produce seed and recruit from the soil seedbank (*Grevillea brachystylis ssp australis* is already doing this on the loamy sand which contained seed before being transferred to this site). However, we also expect there will be high natural attrition rates of the original plantings as many of the plants are too close together. Although at least one species can recruit between disturbance events such as fire, most may only recruit after disturbance. There will also be ongoing natural recruitment of other local species, especially from seed originally sown *in situ* throughout the site. We hope this will all eventually lead to a self sustaining population.

Acknowledgements

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Looking after the bad guys: the conservation of pathogenic fungi

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Pathogenic fungi certainly seem to be bad guys when it comes to their effect on plants. By definition, pathogens are harmful to the host plant. High profile fungal pathogens such as Cinnamon Fungus (*Phytophthora cinnamomi*) have severe effects in bushland, wiping out susceptible plants (many of which are rare or endangered). Pathogens of agriculture and forestry, such as Wheat Stem Rust (*Puccinia graminis*), cause huge costs in crop losses and control. Talk about conserving plant pathogens can lead to suggestions that it would be bad to specifically conserve organisms that can be so detrimental.

But are all the bad guys really that bad? Let's step back from our outrage about the undoubtedly catastrophic effects of Cinnamon Fungus (and the damage caused by powdery mildew on the zucchinis in our vegetable patch) and look more closely at pathogens in natural environments. There are a number of reasons why native pathogens on native hosts might not be as bad as they seem.

Pathogens are not that bad

Firstly, what is wrong with pathogens anyway? Carnivorous animals are accepted as part of the food web, as are herbivores for that matter, so there should be no shirking from looking after leaf spotting fungi just because they happen to 'eat' plants.

Secondly, the most dramatic effects of plant pathogens often occur in un-natural situations: where the pathogen is obviously exotic (as is the case for Cinnamon Fungus in Australia), where there are artificial monocultures (such as in eucalypt plantations), or where hosts are stressed. Changes in forest management can also make pathogens more damaging. For indigenous *Armillaria* root rot in eucalypt forest, Kile (1983) considers that logging practices have aggravated the effects of the pathogen.

Thirdly, 'good parasites don't kill their hosts' (Cannon *et al*., 2001). Some pathogens only affect particular parts of plants (such as leaf undersides or ovaries) and most typically do not kill the host outright. In addition, for a given fungus, there can be degrees of pathogenicity, with an interaction between fungal pathogenicity and the defences of the plant (which often involves a complex interplay of virulence and resistance genes in pathogen and host respectively).

Conservation of pathogens

So, the bad guys should not be overlooked as far as conservation is concerned. Fungi should of course be conserved in their own right, but are also proven sources of biologically active compounds (such as antibiotics). In addition, pathogenic fungi can have beneficial effects, such as production of metabolites that protect host plants from herbivores, and fungi are part of natural food webs, providing food for invertebrates.

There is no up-to-date checklist of Australian pathogenic fungi, and nor has host range been compiled recently. Pascoe (1990) produced an estimate of 250,000 native Australian fungi, using a 10:1 ratio of fungi to vascular plants. This ratio essentially deals with plant pathogenic fungi, and was derived from data on the numerous fungi that are already known to be associated with well-studied crop plants. Hawksworth (1991) used a 6:1 ratio when estimating global fungal biodiversity at 1.5 million species. These estimates are quite crude and depend on assumptions about host range. Host specificity may be at the species or genus level, or fungi may have very wide host ranges. As an example, there are four species in the Australian endemic disc fungus genus *Banksiamyces*, all restricted to *Banksia*. One species, *Banksiamyces macrocarpus*, is found only on *Banksia spinulosa*, with the others occurring on few to many host species. Numerous other fungi will occur on *Banksia*, some restricted to the host genus, or to particular host species.

Whatever the true ratio of fungi to plants, it is clear that there are numerous pathogenic fungi on native hosts, and that most species are as yet undescribed. The great diversity of pathogenic fungi means that a significant number of them could be rare or endangered, although none have been formally listed on Australian conservation schedules under commonwealth, state or territory legislation.

Rare fungi on rare plants

Thers is a special class of potentially rare or endangered fungi restricted to hosts that are rare or endangered. An example from New Zealand is *Puccinia embergeriae* (Chatham Island Sow Thistle Rust) which is known only from one population of *Embergeria grandifolia* (Chatham Island Sow Thistle). The fungus has recently been listed as one of the 50 most endangered fungi in New Zealand (Buchanan *et al*. 2002). A survey of herbarium collections of fungi in relation to their occurrence on 396 New Zealand rare plants found that most such plants had no fungi at all reported from them (Buchanan *et al*. 2002). Apart from *Puccinia embergeriae*, only four other named fungi were found, although a number of collections identified only to genus were located (and these would be of interest for further taxonomic study). There is no compilation of the fungi of rare or endangered Australian plants.

Lack of information about pathogens of rare and threatened plants not only overlooks possibly rare host-limited fungi, but also potential threats to the plants through attack by pathogens. Cannon *et al.* (2001) point out the value of 'health audits' of rare plants, especially in relation to hosts in environments subject to modification (such as encroaching agriculture) where alien fungi may cause problems. Management of a rare fungus on a rare plant may require balancing the needs of pathogen and host, but the mere possibility of such fungi having a detrimental effect on the host should not rule out efforts to conserve fungi in general.

Rare fungi on common plants

If the host is common, it cannot be assumed that any host-specific pathogens associated with the host are also common. An example is Tangled Lignum Rust (*Uromyces politus*), which forms tiny cluster-cups on tangled lignum (*Muehlenbeckia florulenta*), which is a common and widespread plant found throughout Australia. The fungus is on the target list of the Fungimap scheme, but has only been recorded once in the ten years of the scheme (compared to a mean recording level of more than 100 records across the 100 target species). The record is from Victoria, and was a result of intensive searching by Ed & Pat Grey in the vicinity of the only known Victorian locality (Kerang), from where the most recent record of the fungus was from 1905. Thus, in Victoria the fungus could well be much rarer than the host.

Strategies for pathogen conservation

Pathogenic fungi are a large part of fungal biodiversity, but are not well known taxonomically and ecologically because so many are microscopic. Conservation of all groups of fungi lags behind that of other biota (May, 1997). The more visible macrofungi (such as mushrooms) are not as poorly known as the microfungi, and for macrofungi it should eventually be possible to determine conservation status species by species, as has been done for plants. However, this approach is unlikely to be feasible for megadiverse groups such as pathogenic fungi, and strategies need to be developed to deal with conservation of microfungi, taking into account the great diversity and the large number of undescribed species. A focus on a limited range of flagship species (even to the point of formal listing of a few species) could be useful to raise the profile of microfungi. For the other species, known and unknown, the efficacy of existing conservation measures (such as the reserve system) and management practices (such as fire regimes) need to be tested in regard to maintaining microfungal diversity, perhaps by use of sets of indicator species, representative of taxonomic and ecological diversity.

Somewhat paradoxically, given the bad press pathogens receive, healthy ecosystems are those that support a diversity of indigenous pathogenic fungi!

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Phytophthora ramorum: a threat to Australia?

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What makes *Phytophthora cinnamomi* such a devastating plant pathogen in the Australian environment?

- It is a microscopic organism that lives in soil and plant roots.
- It can, and has, spread widely in many Australian landscapes through movement of infested soil from one location to another, naturally and by human activities ranging from bushwalking to mining.
- It can reproduce asexually and prolifically when conditions are optimal (warm and moist).
- It infects a very broad range of plants, and the susceptibility of much of Australia's unique flora indicates that it is exotic in origin.
- Once present in a landscape it cannot be eradicated, although management is possible with commitment from governments, industry and the community.

It's a fairly grim scenario…but it couldn't get any worse…could it? Unfortunately, it could! Imagine a species of *Phytophthora* that has all the characteristics of *P. cinnamomi*, but also has the capacity to be carried by wind-driven rain. *Phytophthora ramorum* is just such a pathogen.

P. ramorum was first discovered in 1993 on rhododendrons in Dutch and German nurseries. Within approximately 10 years it had been isolated from 300 nurseries across the UK, and nurseries in 9 other European countries, mostly from the popular garden shrubs rhododendron, viburnum, pieris and camellia (Pain 2004). The first signs of disease caused by *P. ramorum* in the US appeared on oak trees in San Francisco in 1995 (Werres *et al.* 2001). The disease has now reached epidemic proportions in some areas of California and extends 650 km along the Pacific coastline from Monterey to southern Oregon (Rizzo and Garbelotto 2003). The disease caused by *P. ramorum* has become widely known as 'Sudden Oak Death', which is misleading, because we now know that the host range is much broader.

P. ramorum causes two different diseases: large cankers on the main stem of oaks (*Quercus* spp.) and Tanoaks (*Lithocarpus densiflora*) that often kill the tree, and non-lethal foliar and twig infections on a wide range of plant species. Information from the US Department of Agriculture website (accessed 05/04/05), current as of the 10th January 2005, lists 31 proven hosts (i.e. *P. ramorum* has been isolated from naturally infected plants, and experiments have confirmed that the species can be infected by the pathogen) and 37 associated plants (i.e. *P. ramorum* has been isolated from naturally infected plants, but experiments have yet to be conducted to determine if they are hosts). As well as *Quercus* spp. and *Lithocarpus densiflora*, the proven hosts include species from the following genera: *Acer, Camellia, Photinia, Pieris, Pseudotsuga, Rhododendron, Rosa, Umbellularia, Viburnum* and the iconic *Sequoia* (Giant Redwoods). Plant species that are not killed appear to serve as a reservoir for the pathogen (Rizzo and Garbelotto 2003).

The origin of *P. ramorum* and most details of its biology and ecology remain unknown, but the high susceptibility of Tanoak suggests that *P. ramorum* is exotic to the US (Rizzo and Garbelotto 2003). Some scientists believe that unregulated international plant movements in the horticultural trade were responsible for the introduction (Hansen 2003). The problem is compounded by the use in nurseries worldwide of chemicals that suppress pathogens but do not kill them, so that infected plants can appear healthy to the consumer, and viable pathogens can be transmitted to home gardens and the broader landscape.

The suggested link between the introduction and spread of *P. ramorum* in the US and the international and national trade in plants has had a big impact on the nursery industry. In the US the nursery industry, which is concentrated in California and Oregon, is the third-highest value crop category in the US (Regelbrugge 2003). The imposition of a complete ban by some states on plants from California, and regularly updated federal regulations due to the epidemic, has the nursery industry reeling (Purdue University website, accessed 07/04/05). Earlier this year the US Department of Agriculture (USDA) issued new restrictions on the movement of nursery stock from California, Oregon and Washington (Landscape Management website, accessed 07/04/05).

It will be many years before the impacts of *P. ramorum* on natural ecosystems and biodiversity in the US are fully realised and understood. However, it is already clear that dieback of native vegetation has created a habitat ripe for exotic weed invasion and soil erosion and has degraded wildlife habitat (Frankel 2003). The socio-economic impacts are already being widely felt. In the coastal counties of California, where 'Sudden Oak Death' was first recognised and where susceptible species are concentrated, the wildland-urban interface is heavily populated. The increasing number of large, dead trees in these areas poses a number of problems including the high cost of tree removal, the increased risk of fire and damage to life and property if they are not removed, the loss of amenity and recreation values, a reduction in property values, public fear about the potential of the disease in their gardens and forest,

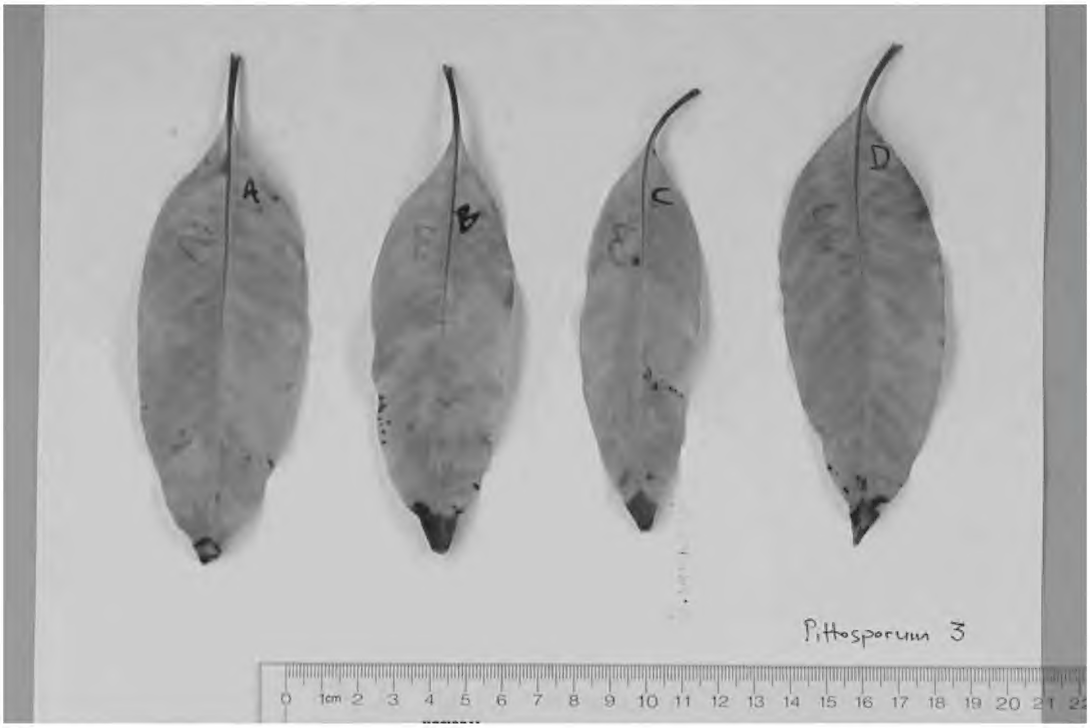

Figure 1. Leaves of Pittosporum undulatum *32 hours after they were inoculated with* Phytophthora ramorum *in trials in the US.* Pittosporum undulatum *is native to moist gullies in rainforest and sclerophyll forest from south-east Queensland to eastern Victoria, areas which are considered conducive to the establishment* of Phytophthora ramorum.
Source: Pathology and Mycology Laboratory, University of California, Berkeley

and initial outrage at what was perceived as insufficient action by the authorities to control it (Frankel 2003).

You may be wondering what all this has to do with Australia? It has plenty to do with us, for the simple reason that Australia also imports and exports plants as part of the worldwide nursery trade that has been implicated in the introduction of *P. ramorum* to the US. Historically, visual inspection of imported material has been the primary defence against introducing new pests/pathogens to an importing country (Regelbrugge 2003); however *Phytophthora* spp. can be present in the soil or in the plant without being apparent, even to the trained eye.

A recent evaluation of climatic conditions in Australia showed that many productive forests, old growth forests and temperate rainforests could be conducive to *P. ramorum* disease development (Smith *et al*, unpublished data). Some limited field observations and pathogenicity tests have indicated that a number of Australian species native to these high risk areas, including *Eucalyptus gunnii* (Brown unpublished data), *Nothofagus* sp (Brown, unpublished data) and *Pittosporum undulatum* (Hüberli *et al.*, unpublished data; Figure 1), are susceptible to *P. ramorum.*

P. cinnamomi and *P. ramorum* reproduce through the production of sporangia (see Fig 3 of Summerell et al. article on page 4). However, sporangia of *P. cinnamomi* remain attached to the main body of the pathogen (the mycelium) and thus remain in either infested soil or plant tissue, whereas the sporangia of *P. ramorum* break off the mycelium when they are mature and can then be carried in wind and wind-driven rain. In the event that *P. ramorum* was accidentally introduced to Australia, humans would pose the greatest risk in spreading the pathogen in the landscape, just as they do for *P. cinnamomi*. However, the fact that *P. ramorum* can also be spread by wind-driven rain means that the current containment methods for *P. cinnamomi* would not be directly transferable to or as effective for *P. ramorum*.

It is clear that action needs to be taken immediately in Australia to: a) guard against the introduction of *P. ramorum;* b) determine the risk of an introduction to Australia; and c) develop an emergency containment and management strategy in the event of an introduction. Current research proposals for collaborations between Australia, the UK and US will address the issues of preparedness and prevention of an incursion to Australia, and management of an incursion should quarantine measures fail.

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New records for the endangered *Hibbertia procumbens* from the Central Coast of NSW

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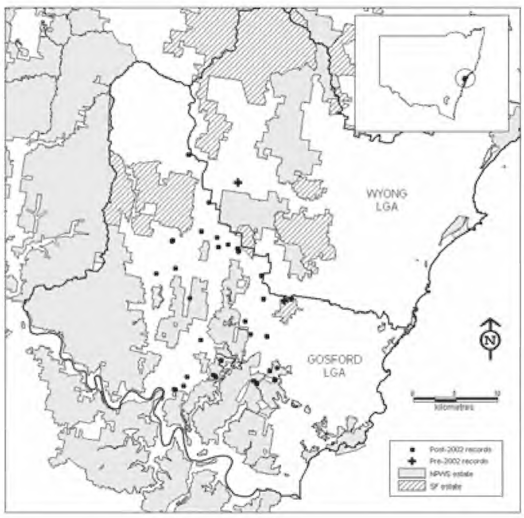
Hibbertia procumbens (Labill.) DC (Dilleniaceae) is a summer-flowering prostrate shrub, currently listed in New South Wales as endangered under the *Threatened Species Conservation Act 1995*. Harden and Everett (1990) noted in the *Flora of New South Wales* that this species was known only from the Mangrove Mountain area of the NSW Central Coast. However, it is also present in Victoria and Tasmania, where it is locally common. It is likely that all New South Wales specimens may represent a new, currently undefined taxon (H. Toelken, pers. comm.).

In a review of the habitat of this species at the two then known locations, Bell (2002) suggested that with concerted survey effort in heath and scrub vegetation, it was likely that additional populations would be located. In recent years, a combination of targeted survey and more general vegetation survey, both by us and other workers, has significantly increased the number of known populations of this species. Currently, there are at least 30 known populations in NSW, with a distribution extending from the city of Gosford north to near Yarramalong, and west to the Popran National Park area (see map).



Known populations of Hibbertia procumbens *on the Central Coast of NSW*

New populations

As part of the development application process required under state planning legislation, searches for and assessment of threatened species are mandatory. Several workers have discovered a number of new populations of *Hibbertia procumbens* on private lands as a consequence of this process. Detailed population counts have been undertaken at some of these (eg: Bell & Driscoll 2003), where populations in the order of 1000 plants have been found. Ground-truthing of regional vegetation mapping has also uncovered new populations, simply by targeting potential habitat in a number of representative areas (Bell 2004).

Hibbertia procumbens *growing in a road cutting, Mangrove Mountain. Photograph: Stephen Bell*

In 2002, no populations of *Hibbertia procumbens* were known from secure conservation reserves, although one was present in Strickland State Forest. However, populations have now been found in Brisbane Water and Popran National Parks, and the Howe Aboriginal Area near Somersby. Other populations have also been uncovered in the Mangrove Dam catchment area where public access is restricted. In many cases, populations of *Hibbertia procumbens* occur with other threatened plant species, including *Acacia bynoeana* (endangered), *Eucalyptus camfieldii* (vulnerable), and *Tetratheca glandulosa* (vulnerable). In nearly all populations, the related *Hibbertia empetrifolia* subsp. *uncinata* is also present, a poorly known subspecies of *H. empetrifolia* which Toelken (1998) defines as being restricted to the Kulnura-Mangrove Mountain area. Harden and Murray (2000) note that this rarely collected taxon is insufficiently understood, and prior to recent studies had not been collected since 1965.

Habitat

Previously, habitat for *Hibbertia procumbens* was documented as scrubby-heath dominated by *Angophora hispida* and *Banksia ericifolia*, on skeletal sandy soils of the Hawkesbury Sandstone (Bell 2002). However, recent finds have included the additional habitats of trail edges and locally disturbed areas in open forest of *Eucalyptus haemastoma-Corymbia gummifera*, and small sandy rises associated with hanging swamps (Bell, Parsons & Meldrum 2005). All of these habitats are prone to frequent fire; however *Hibbertia procumbens* resprouts readily and flowers prolifically when the shrub layer is reduced in density. Seed set and viability remain to be investigated, but, as in other *Hibbertia* species, it is likely that a dormancy mechanism operates on the seed.

Current status

In the space of just four years, the number of known populations of *Hibbertia procumbens* in NSW has jumped from one prior to 2000, to over 30 in 2004. As a result of the new populations recently discovered, the future of this prostrate shrub appears promising, especially as many of the populations are within protected areas. Given the extent of potential habitat in the Yengo National Park, as well as Dharug and Wollemi National Parks further to the west, Jilliby State Conservation Area to the east, and Marramarra National Park and Muogamarra Nature Reserves to the south, it is likely that several additional populations await discovery following targeted survey. The value of targeted searches as demonstrated here should serve as a lesson for many other threatened plants.

Acknowledgements

Thanks to Mark Stables, Geoff Cunningham and Barry Collier for information on some new populations of *Hibbertia procumbens*.

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Managing low genetic diversity in *Acanthocladium dockeri*

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Acanthocladium dockeri, or the Spiny Daisy, is the only species in the genus *Acanthocladium* (Asteraceae) and is endemic to Australia. Until recently it was thought to be extinct, but in August 1999 it was rediscovered about 6 km east of Laura in the mid-north of South Australia (Jusaitis and Bond 1999). Three populations were found within a radius of about 4 km, and a further population was discovered 70 km further south, near Brinkworth. All four populations (named Thornlea, Yangya, Hart and Rusty Cab) occur along roadsides, and the total number of plants was recently estimated at 2900 (Robertson 2002).

Each population is relatively small and compact in structure. Excavation of plants at each site revealed that plants multiplied vegetatively by root suckering (Jusaitis and Bond 1999; Figure 1). To date no seedlings have been observed at any population site. These observations raised the possibility that each population may be more or less clonal. At best, poor seed production and seedling recruitment, combined with an inherent capacity for vegetative proliferation, suggested that genetic diversity within each population was likely to be low.

We carried out allozyme studies which confirmed that *A. dockeri* is clonal, possessing only a single genotype at each of the four known population sites. Thus, the recent survey estimate of 2900 plants in four populations (Robertson 2002) considerably overestimated the true number of genetically distinct individuals. We also showed that even though *A. dockeri* flowers prolifically, very few viable seeds were produced. This extremely low level of sexual reproduction appears to be related to low pollen viability and germination. Approximately 0.2% of pollen grains were capable of germination. Grains that did germinate showed extremely slow, sometimes deformed growth of the pollen tube.

Poor seed set in an otherwise apparently healthy population can be an indicator of possible clonality or a lack of pollinators (Peakall and Sydes 1996). However, a range of pollinating insects were observed working flowers of *A. dockeri* at the Hart population, and so it is unlikely that pollination is a problem.

Implications for conservation management

The apparent lack of genetic diversity at each population site, extremely low levels of seed set, population growth by clonal reproduction rather than seedling recruitment, and degraded roadside habitats potentially menaced by weeds and grazing, all combine to threaten the long-term persistence of *A. dockeri*. With the low number of remnant populations, each comprising a single genetic clone (genet), the loss of any one population would result in a substantial (25%) reduction in the genetic diversity remaining within the species.

Therefore it is crucial to preserve all four remaining genets in their respective habitats, ensuring each population is secure and local threats are eliminated or controlled. Management actions for this vegetatively regenerating species should be designed to optimise vegetative recruitment (Coates *et al*. 2002) and prevent loss of habitat. As a first step, roadside markers have been installed at each *A. dockeri* population site to alert road-maintenance workers to the presence of a significant site requiring sensitive care and appropriate operational procedures.

Vegetative proliferation of shoots from an underground root of A. dockeri *exposed by digging. Photograph: Manfred Jusaitis*

A comprehensive *ex situ* collection encompassing the full extent of known genetic diversity is possible for this species because of the clear-cut geographical segregation of genets. A single plant could be taken from each population and multiplied through vegetative propagation. We also need to urgently find more populations which may contain new genets with superior fertility. If male fertile individuals are found, the introduction of fertile pollen into male sterile populations could help to reintroduce fertility to these populations.

The clonality of these *A. dockeri* populations also has important implications when planning plant translocation programs. There is little point in augmenting existing populations, given their clonal nature. Populations already appear to be at their optimal density given present levels of

competition, and there seems to be nothing preventing them from expanding further. And with such poor seed set there is no advantage in mixing genetically distinct clonal populations. Preliminary trials showed no improvement in fecundity when clones from Hart and Thornlea were crossed together. Furthermore, we do not understand the potential consequences of mixing genotypes from different populations of *A. dockeri*. Therefore we recommended avoiding mixing genets in natural populations, until we understand such interactions better.

There may, however, be a valid argument for spreading risk or enhancing population security by developing new populations of *A. dockeri* through translocation to secure sites. Transplants may be derived either vegetatively (cuttings or tissue culture), or from seed collected at one or more populations. Seedlings will tell us more about the reproductive system of this plant, and may furthermore present an opportunity to introduce fertility back into the population. However, before starting large-scale translocations like this, the possible consequences of segregating *vs.* mixing genotypes or provenances should be evaluated using carefully planned experimental translocations designed specifically to study competitive, reproductive and genetic outcomes (Jusaitis 1997).

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Saving the Ridged Water-milfoil

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Last year, I came across an unusual plant in a small granitic rock pool on a parcel of unreserved Crown land controlled by the Loddon Shire Council. The area adjoins the southern boundary of the Terrick Terrick National Park and was formally a granitic gravel quarry. This management left the landscape with a 'pock-marked' appearance, creating numerous small ephemeral waterholes; ideal habitat for the annual aquatic herb Ridged Water-milfoil (*Myriophyllum porcatum)*. I was searching potential habitat for the species, and this find, although only 10 square metres in size, was particularly exciting as it increases the known populations in the Terrick Terrick National Park area by 50%.

Myriophyllum porcatum is perhaps one of the Victorian Riverina's most unique species. It is found in some of the Murray River's tributaries and small farm dams, and all the way up to the ephemeral granitic rock-pools on top of Terrick Terrick National Park. While this does not sound particularly extraordinary *per se,* what is special about *M. porcatum* is expressed in the Recovery Plan: "there are fewer than 250 plants remaining in approximately nine wild populations" in Victoria (Murphy, 2003; see Figure 1).

Figure 1: Known populations of Ridged Water-milfoil in Victoria.

Wetland communities in the Murray-Darling Basin have been significantly depleted as a result of drainage, with currently only 11% remaining (Bunn, *et al.* 1997). All of the *Myriophyllum procatum* populations are found at a significant distance from each other, often within highly disturbed environments such as pastures and cropped areas. The species is listed as Vulnerable under the Commonwealth *Environment Protection and Biodiversity Conservation Act* (EPBC) *1999*, and as Threatened under the Victorian *Flora and Fauna Guarantee Act* (FFG) *1988*.

Figure 2: 15-year-old Julian Geldard collecting herbarium specimens. Photograph: Miles Geldard

Species in the *Myriophyllum* genus are distinguishable by their mature fruit. In the case of *porcatum*, the fruit are cylindrical and ribbed, 1.8 to 2.1mm in length and 0.9 to 1.2mm wide (illustrated in Orchard, 1981.) It is this feature that the Melbourne Herbarium's John Reed used to positively identify the specimen I found last year.

It is my responsibility to coordinate the Recovery Plan for Ridged Water-milfoil, written by Anna H. Murphy (2003), with funding from the National Heritage Trust. The overall objective of recovery is to minimise the probability of extinction of Ridged Water-milfoil in the wild and to increase the probability of important populations becoming self-sustaining in the long term. Within the life span of this recovery plan (2004-2008), the specific objectives are to:

- acquire accurate information for conservation status assessment;
- identify critical, common and potential habitat;
- ensure that all populations and their habitat are protected and managed appropriately;
- manage threats to populations;
- identify key biological functions;
- determine growth rates and viability of populations;
- establish populations in cultivation;
- build a network of government and non-government organisations and individuals; and
- cooperate in bioregional policy implementation and manage recovery plan implementation.

The status of the land where I found this new population is currently under review and it is assumed that it will soon become another addition to the Terrick Terrick National Park.

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Short Notes

Phytophthora cinnamomi threat abatement plan to be reviewed

Dieback caused by the root-rot fungus *Phytophthora cinnamomi* is listed as a 'key threatening process' under the Australian Government's *Environment Protection and Biodiversity Conservation Act 1999*. Following this national listing a threat abatement plan was developed in 2001 having two broad goals: to protect nationally listed threatened species and ecological communities from *Phytophthora cinnamomi*; and to reduce the chance of other species and ecological communities become exposed.

The Australian Government's $3 billion Natural Heritage Trust has provided funding for national coordination and implementation of this threat abatement plan. This funding is going towards research to better understand the ecology and spread of the pathogen and its effects on Australian ecosystems, as well as the development of techniques and tools for managers, including communiction activities. While eradication of *Phytophthora cinnamomi* does not seem possible at present, we hope to restrict the intensification and spread of known infestations and limit spread to new sites.

The Australian Government Department of the Environment and Heritage has begun a review of the threat abatement plan. If you have any comments or wish to be involved in this review, please contact Belinda Parkes at belinda.parkes@deh.gov.au. Additional information on the plan and related projects being funded by the Australian Government can be found at:

http://www.deh.gov.au/biodiversity/threatened/publications/tap/phytophthora/index.html

http://www.deh.gov.au/biodiversity/invasive/index.html

How good are we at predicting the field host-range of fungal pathogens used for classical biological control of weeds?

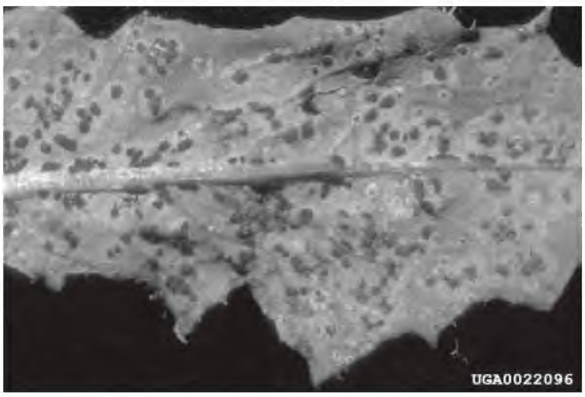
After release, a classical biocontrol agent is expected to become a permanent part of its new environment and it is vital to ensure, as far as possible, that it will do more good than harm there. This is done through risk assessment, which invariably includes host-range testing.

The use of pathogenic fungi as classical biological control agents for weeds began in 1971. To date, 26 species of fungi, originating from 15 different countries, have been used as classical biocontrol agents against over 26 species of weeds in 7 countries.

A recent paper by Barton (née Fröhlich) (2004) presents a review of the performance of these pathogens in the field after release, compared with predictions made on the basis of pre-release host-range testing. No reports were uncovered of deliberately introduced fungi unexpectedly attacking non-target plants after release. Indeed, host-range testing results have often proved conservative, with a number of examples of pathogens attacking non-target plants in pre-release tests, but not being recovered from these species in the field.

Barton concluded that risk assessments based on rigorous host-range testing, combined with a good understanding of the taxonomy, biology, and ecology of the agent, the target weed, and non-target species, can ensure that the introduction of exotic pathogens is a safe and environmentally benign method of weed control.

For a full copy of research paper see: Barton (née Fröhlich), J. 2004. How good are we at predicting the field host-range of fungal pathogens used for classical biological control of weeds? *Biological Control* 31: 99–122.



*Skeleton weed rust (*Puccinia chondrillina*). This was the first micro-organism to be released as a classical biocontrol agent; it was introduced to Australia in 1971. Photograph: Gary L. Piper, Washington State University, www.forestryimages.org*

Research Roundup

Adams, V.M., Marsh, D.M. and Knox, J.S. (2005). **Importance of the seed bank for population viability and population monitoring in a threatened wetland herb.** *Biological Conservation* 124 (3): 425-436.

Andersen, A.N., Cook, G.D., Corbett, L.K., Douglas, M.M. and Eager R. (2005). **Fire frequency and biodiversity in Australian tropical savannas: implications from the Kapalga fire experiment.** *Austral Ecology* 30(2): 155-167.

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Jusaitis, M. (2005) **Translocation trials confirm specific factors affecting the establishment of three endangered plant species.** *Ecological Management and Restoration* 6(1): 61-67.

Kirkpatrick, J.B., Gilfedder, L., Bridle, K., Zacharek, A. (2005) **The positive and negative conservation impacts of sheep grazing and other disturbances on the vascular plant species and vegetation of lowland subhumid Tasmania.** *Ecological Management and Restoration* 6(1): 51-60. .

Lumsden, L.F. and Bennett, A.F. (2005). **Scattered trees in rural landscapes: foraging habitat for insectivorous bats in south-eastern Australia.** *Biological Conservation* 122(2): 205-222.

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Rymer, P.D., Whelan, R.J., Ayre, D.J., Weston, P.H. and Russell, K.G. (2005). **Reproductive success and pollinator effectiveness differ in common and rare *Persoonia* species (Proteaceae).** *Biological Conservation* 123(4): 521-532.

Web Freebies

Noxious and Environmental Weed Control Handbook 2004-2005

Rod Ensbey, NSW Agriculture, 2004

A guide to weed control in non-crop, aquatic and bushland situations. This comprehensive guide provides a useful overview of integrated weed control methods and contains information on pesticide and worker safety, reducing herbicide spray drift, record keeping, herbicide resistance, guidelines for controlling specific noxious and environmental weeds, and much more. Available at http://www.agric.nsw.gov.au/reader/weed-pubs/nox-weeds-splash.htm

Communicating for Recovery – a guide to developing a Recovery Plan Communications Strategy

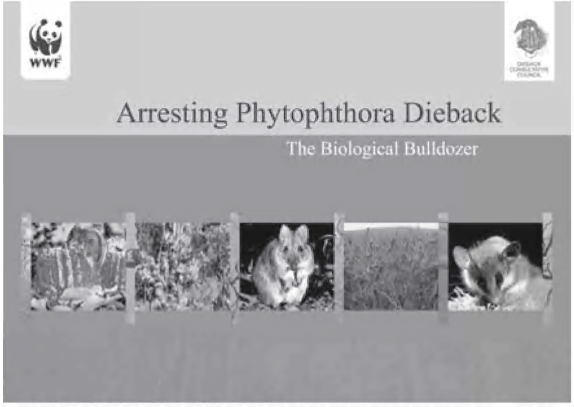
Russell et al, WWF Australia, 2004

This document provides a guide for recovery teams in the development of a Communications Strategy that will help foster and deliver recovery objectives. It provides a model that recovery teams can adopt to ensure that their communications with key stakeholders are relevant, strategic, cost-effective and accountable. Although the guide has been developed with threatened species recovery teams in mind, the steps and principles can be applied equally to any *in-situ* conservation project where the main threats have been identified. Available at www.wwf.org.au/News_and_information/Publications/, or can be obtained by contacting WWF on 1800 032 551.

Arresting *Phytophthora* Dieback - the Biological Bulldozer

WWF Australia, 2004

Outlines the effects of *Phytophthora* dieback on Australia's native plants and animals. It provides information on the biology of the disease, its impact on the landscape, how it spreads, case studies of the impact on our native fauna, and what we, as a community, must do to "Arrest the threat". Available at www.wwf.org.au/ News_and_information/ Publications/, or can be obtained by contacting WWF on 1800 032 551.



Conferences and Workshops

8th International Workshop on Seeds

8-13 May 2005, Brisbane, Queensland

Conference theme is Germinating New Ideas, focusing the workshop on the recent changes in seed science research and practise. Specific topis include: seed development, seed germination and dormancy, seed desiccation and conservation, seed ecology, and seed biotechnology and seed biology of Australian native species. Additional information available from http://www.seedbio2005.asn.au.

4th International Symposium/Workshop on Frugivores & Seed Dispersal

9- 16 July 2005, Griffith University in Brisbane, Queensland

Symposia topics include: roles of animal seed dispersers in revegetation; frugivory and seed dispersal in fragmented landscapes, and frugivores & plant invasions. For further details, see: http://www.learnaboutwildlife.com/Frugivory2005.htm.

NZ Plant Conservation Network Conference 2005: 'Restoring our threatened plant life – empowering our community'.

12-14 August 2005, Christchurch, NZ

This will be an exciting event for anyone interested in protecting, growing or studying New Zealand's native plants. Speakers at the conference will include Professor Ian Spellerberg (Lincoln University), Hugh Wilson, Brian Molloy, Gerry McSweeney, Colin Meurk and Peter Heenan (Landcare Research), Jorge Santos, Nick Head and Anita Spencer (Department of Conservation), Mike Peters (New Zealand Ecological Restoration Network) and Rick Menzies (Banks Peninsula Trust). There will also be a series of plant conservation workshops including one on threatened plant propagation. David Given will present a public lecture on the future of the native plant life of Canterbury on the evening of Friday 12th August at the same venue. For further details see: http://www.nzpcn.org.nz

National Conference of the Australian Network for Plant Conservation: Plant Conservation; The challenges of Change

26 September–1 October 2005, Adelaide, South Australia

The ANPC and the South Australian Department for Environment and Heritage invite you to Adelaide to exchange ideas and to participate in discussions on the challenges that currently face us all in plant conservation. Whether these be challenges of changing climates, changing environmental conditions, changes in government and policy focus, or confronting scientific information, this conference will stimulate consideration and participation. Conference sub-themes include: 1. Extreme policy changes, 2. Urban ecology, 3. Using revegetation to achieve ecological outcomes, and 4. Indigenous interests in conservation. The conference will appeal to all those involved in plant conservation from the on-ground practitioners to researchers and policy makers. All are invited to share experiences in managing for conservation in times of change and uncertainty. For additional information go to www.pelvin.com.au/ANPC2005 and see the back page of this issue.

Growing Wetlands: International Wetlands Conservation and Restoration Workshop

Early November 2005, Perth, Western Australia.

This workshop aims to review current global good practice in wetland restoration and wetland biodiversity management, particularly within an urban context. For further information contact Deanna Rokich on ph: 08 94803623, email: drokich@bgpa.wa.gov.au.

Eighth International Mycological Congress

20–26 August 2006, Cairns, Queensland

Will be the first International Mycological Congress held in the Southern Hemisphere. You can register interest online at http://www.sapmea.asn.au/conventions/imc8/index.html

ANPC Workshops

Workshops on the management and rehabilitation of disturbed native vegetation

19-20 July, UNE, Armidale
14-15 September, Wagga Wagga (dates to be confirmed)
25-26 October, Dubbo (dates to be confirmed)

The ANPC is offering three workshops on native vegetation rehabilitation in regional NSW this year. These workshops will suit a range of management and rehabilitation goals and will focus on the ecological principles that determine successful rehabilitation planning, update participants on reforms in legislative requirements, and encourage the exchange of skills and knowledge derived from practical experience and research.

Much of our remaining native vegetation occurs on land that is managed for purposes apart from biodiversity conservation. Those responsible for managing powerlines, road and rail easements, travelling stock reserves, water catchments, council reserves or pastoral land can be daunted by legal and public expectations that they be expert conservationists! Even for practitioners committed to conservation outcomes, planning a rehabilitation project requires a broad spectrum of knowledge and skills.

These workshops will be of interest to anyone involved in native vegetation rehabilitation and management, such as: local councils, state government agencies, utilities providers (eg power and water), managers of stock reserves, road and rail easements, NRM/ biodiversity staff, CMA staff, industry, environmental consultants, Landcare and other community groups, private landholders and other land managers and decision makers.

Presenters will include local practitioners and experts with skills and experience in local and regional issues. Networking is also an important component of the workshop.

Workshop fees (including GST):

ANPC members $165; concession $75 (volunteer community group member, full-time student, pensioner).

ANPC non-members $185; concession $95 (volunteer community group member, full-time student, pensioner).

Workshops on the translocation of threatened plants

Wed 18 May, Queanbeyan
Thur 28 July, Newcastle
Tue 30 August, Coffs Harbour

Due to the success of the ANPC translocation workshops (the workshop has now been held five times across Australia), the NSW Government Environmental Trust has provided support to enable the ANPC to hold the workshop at three regional areas within NSW. The workshop is aimed at anyone involved in the planning, approval or implementation of translocation projects for threatened flora. The workshop is particularly relevant for local government staff involved in the development approval process. Participants in the course will not only gain substantial knowledge on the day but will also receive a copy of the *Guidelines for the Translocation of Threatened Plants.* This guide is usually valued at $22 and its content is supported by the Commonwealth Natural Resource Management Ministerial Council and the New South Wales Department of Environment and Conservation.

Environmental TRUST

The workshop fee is only $50 due to the financial assistance of the NSW Government Environmental Trust. This represents a significant cost saving as the workshop is usually $85 for ANPC members and $115 for non-members.

The first workshop will be held at Queanbeyan on 18th May. A detailed program and registration form are now available from the ANPC website. Programs and registration forms for the Coffs Harbour and Newcastle workshops will be available shortly. See the box below for how to find out more.

Further information on these workshops is available on www.anbg.gov.au/anpc (click on "TRAINING"). Programs, flyers and registration forms for each workshop will be posted on the website as they are finalised.

Or contact the ANPC National Office, Phone: 02 6250 9509 or 02 6250 9523 Email: anpc@anbg.gov.au

Accreditation: Participation in ANPC workshops can now contribute to qualifications in the Conservation and Land Management Training Package. Cost is $25 (more information is available on the website at http://www.anbg.gov.au/anpc/course1.html#Courseaccreditation or on request).

Due to the success of previous workshops, the

Australian Network for Plant Conservation

will be holding its workshop on

THE TRANSLOCATION OF THREATENED PLANTS

at three regional centres within NSW

Wednesday 18th May, Queanbeyan
Thursday 28th July, Newcastle
Tuesday 30th August, Coffs Harbour

Environmental TRUST

Registrations now open

See further details on page opposite or visit the website: www.anbg.gov.au/anpc/

Registration fee: $50 (incl GST)
(costs are subsidised by the NSW Environmental Trust)

Photos (left to right): TAFE students assisting with Golden Moth Orchid translocation; Golden Moth Orchids in pots; Golden Moth Orchid in habitat; Golden Moth Orchid; Photos: Paul Scannell, Albury City Council; Tumut Grevillea, Photo: Murray Fagg © ANBG

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Plant Conservation
THE CHALLENGES OF CHANGE
National Conference of the Australian Network for Plant Conservation (ANPC)

26 September to October 1 2005

The National Wine Centre Adelaide, South Australia

The Australian Network for Plant Conservation and the South Australian Department for Environment and Heritage invite you to Adelaide to exchange ideas and to participate in discussions on the challenges that currently face us all in plant conservation.

Whether these be challenges of changing climates, changing environmental conditions, changes in government and policy focus, or confronting scientific information, this conference will stimulate consideration and participation.

The conference will appeal to all those involved in plant conservation from the on-ground practitioners to researchers and policy makers. All are invited to share experiences in managing for conservation in times of change and uncertainty.

The Conference theme is **Plant Conservation: The Challenges of Change.** Sub-themes include:

1. Extreme Policy Changes
2. Urban Ecology
3. Using Revegetation to Achieve Ecological Outcomes
4. Indigenous Interests in Conservation

The Conference will be held at the National Wine Centre, in the environs of the Adelaide Botanic Gardens and adjacent to Adelaide's East End restaurant district. A two day scientific program, one field days and two days of workshops are planned with plenty of opportunity to enjoy Adelaide's fine food and wine.

Abstracts for papers due June 17, see website for futher details.

For futher information contact:

Conference Secretariat
Plevin and Associates Pty Ltd
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Australian Network for Plant Conservation

Botanic Gardens of ADELAIDE

Government of South Australia
Department for Environment and Heritage

www.plevin.com.au/ANPC2005

Australasian Plant Conservation
BULLETIN OF THE AUSTRALIAN NETWORK FOR PLANT CONSERVATION

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